APPENDIX F
Alternative Water Supply Conceptual Design and Estimation

TECHNICAL MEMORANDUM:

Alternative Water Supply Projects Cost Estimation - Stormwater Reuse with Impoundments

This memorandum provides a summary of the conceptual design and planning level cost estimates for a potable water supply project using surface water runoff from the Kissimmee Chain of Lakes, specifically Lake Tohopekaliga (Lake Toho), as a source. The project includes sizing of an aboveground impoundment, inflow and outflow pump stations and seepage control facilities, as well as providing planning level costs estimates associated with diversion, storage and subsequent treatment of water using one of the stormwater treatment technologies. An ultrafiltration treatment technology, developed by ZENON Environmental Inc., which uses the ZeeWeed ultrafilter membrane (UF membrane), was selected as the water treatment technology for the project.

Derived from a study on stormwater availability in the Upper Kissimmee Basin (*A Preliminary Evaluation of Available Surface Water in East Lake Tohopekaliga and Lake Tohopekaliga*, Cai 2005), **Figure 1** shows 32-year average monthly volumes of water available for diversion from Lake Toho. As can be seen from the figure, there is an almost ten-fold difference in Lake Toho water availability between the months of May (4,440 acre-feet) and June (471 acre-feet).

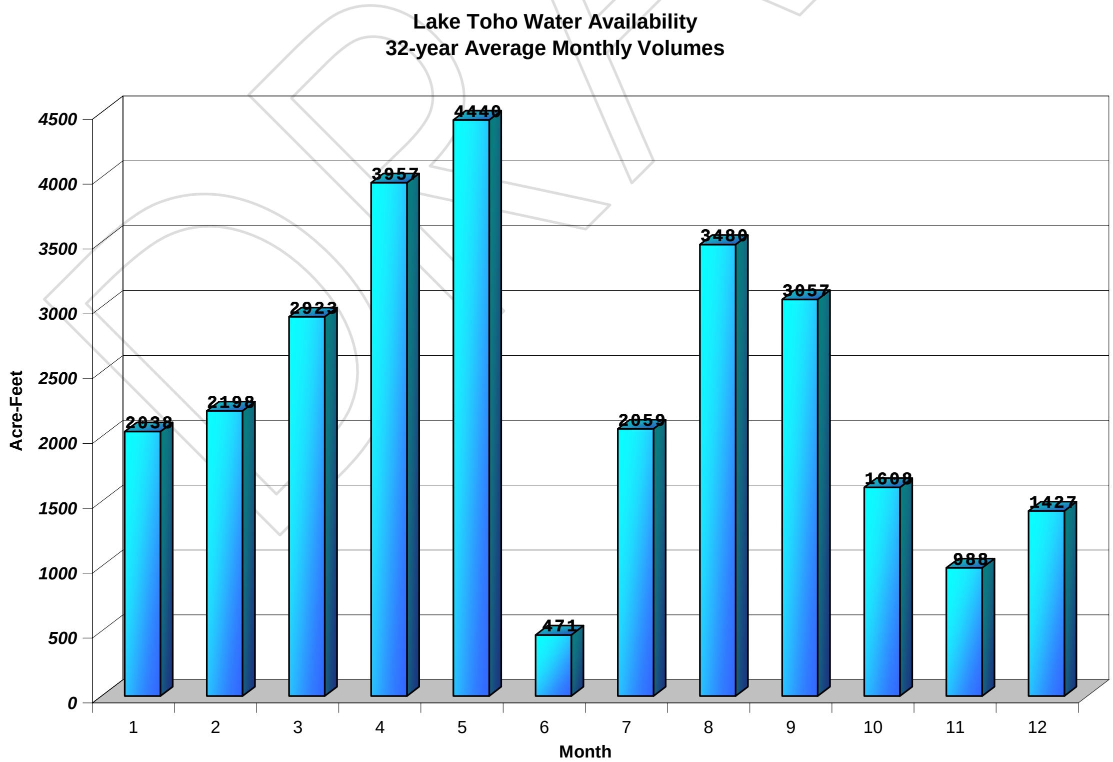

Figure 1. Lake Toho Water Availability.

In order to even out temporal variations of Lake Toho water availability and provide a reliable source of inflow to a water treatment plant, the project includes an aboveground impoundment to divert and store Lake Toho water when it is at, above, or within a certain range below its regulation schedule, and to release water for treatment when water from Lake Toho is not available. In order to size the impoundment, a water budget model was developed to simulate inflow, rainfall into, seepage, evapotranspiration and water treatment plant demand (10, 15 and 25 MGD) on a daily basis from the impoundment for the 32-year (1970–2001) period of record.

The simulation results were summarized by plotting the demand level met against the impoundment size (200, 500, 1,000, 1,500, 2,000 and 3,000 acres), with each curve on the graph representing a different impoundment maximum depth (4, 6 and 8 feet). The plots of spillovers (amount of water available, but not captured in the impoundment due to it being full) as a function of the impoundment size were also provided. The simulation results showed that the seepage losses from the impoundment had to be controlled in order to achieve reliability for the water treatment facility in the 90 to 95 percent range, even for a 10 MGD level of demand.

A second set of simulations consisted of model runs with a seepage recycling rate of 70 percent. The results of the impoundment performance, with 70 percent of seepage recycled back to the impoundment, showed much improved demand levels met for all impoundment sizes and depths. The seepage perimeter canal and the seepage recycling pump station are, therefore, included in the proposed impoundment conceptual design.

Using the results from each model run, the demand level met for every combination of the impoundment size and depth, and the water treatment plant demand (plant capacity) were calculated. For example, for the plant capacity of 10 MGD the range of the demands met is between 7.87 MGD (for a 200-acre 4-foot deep impoundment) and 9.85 MGD (for a 3,000-acre 8-foot deep impoundment), or 76 percent to 98 percent of time, respectively. For a plant capacity of 15 MGD, the range of the demands met is between 11.09 MGD and 14.54 MGD, or 71 to 97 percent of time, respectively. Finally, for a 25-MGD water treatment plant, the range of demands met is between 16.76 MGD and 21.9 MGD, or between 62 and 86 percent of time, respectively.

Figure 2 through **Figure 4** show the demand level met, by volume, as a function of the impoundment size for the 10, 15 and 25 MGD capacity water treatment plants. @ through **Figure 7** show the same relationship with the demand level met expressed as percent of time.

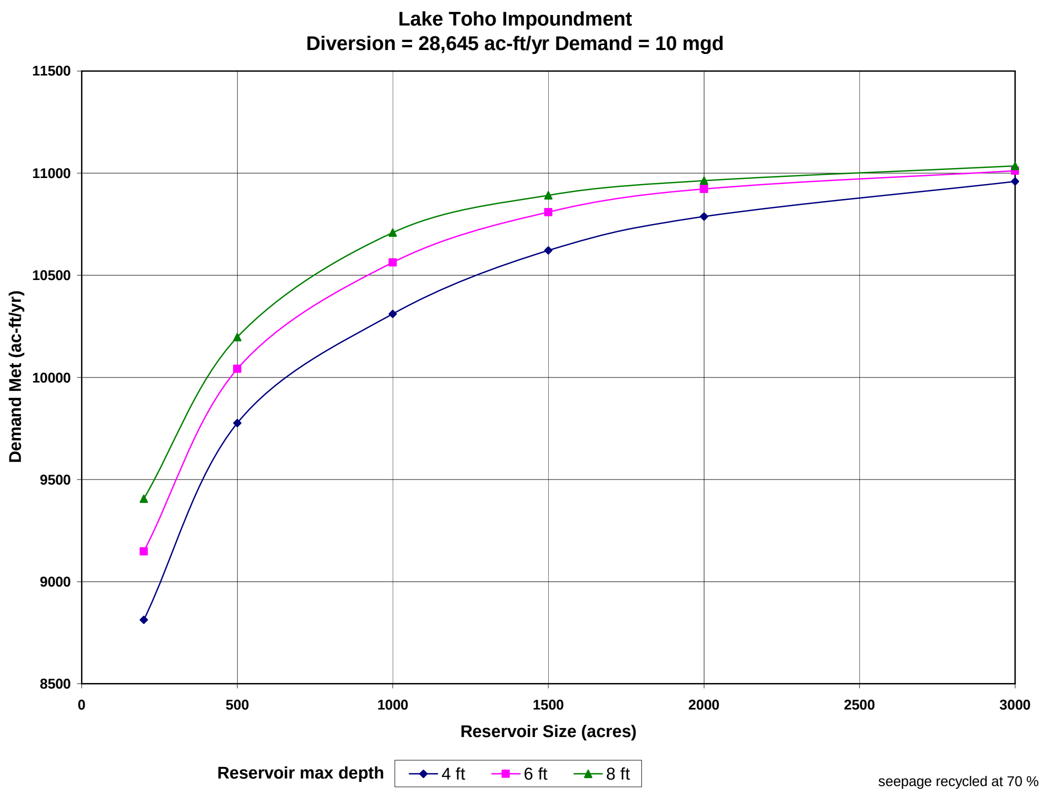

Figure 2. Demand Level Met (by volume) for a 10 MGD Capacity Treatment Plant.

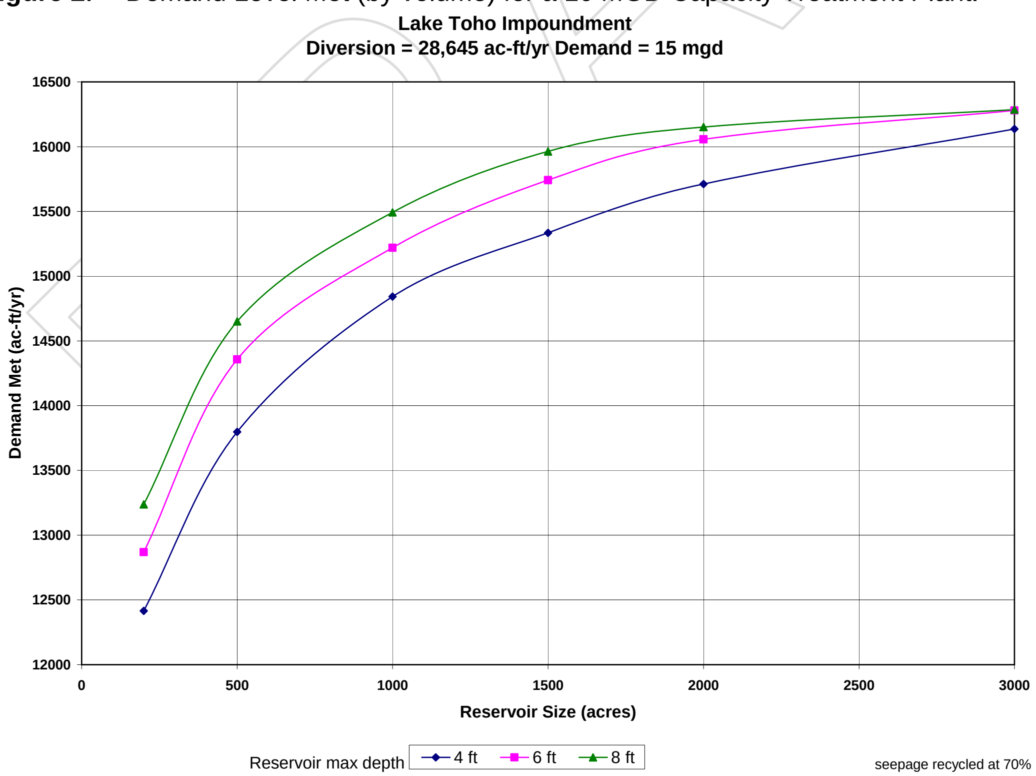

Figure 3. Demand Level Met (by volume) for a 15 MGD Capacity Treatment Plant.

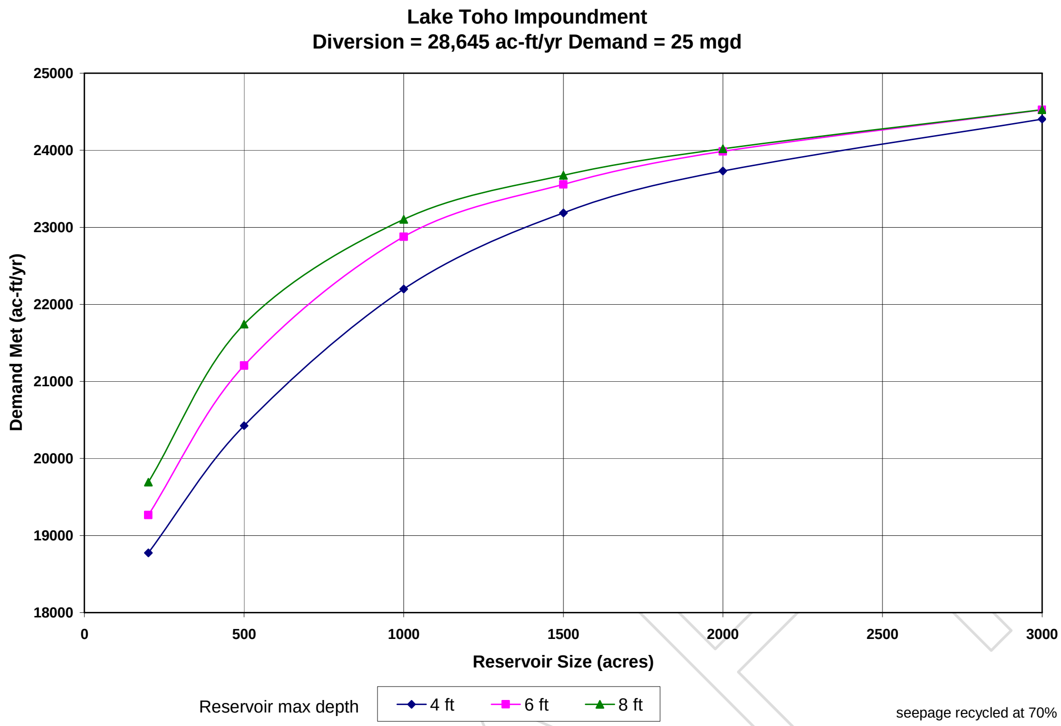

Figure 4. Demand Level Met (by volume) for a 25 MGD Capacity Treatment Plant.

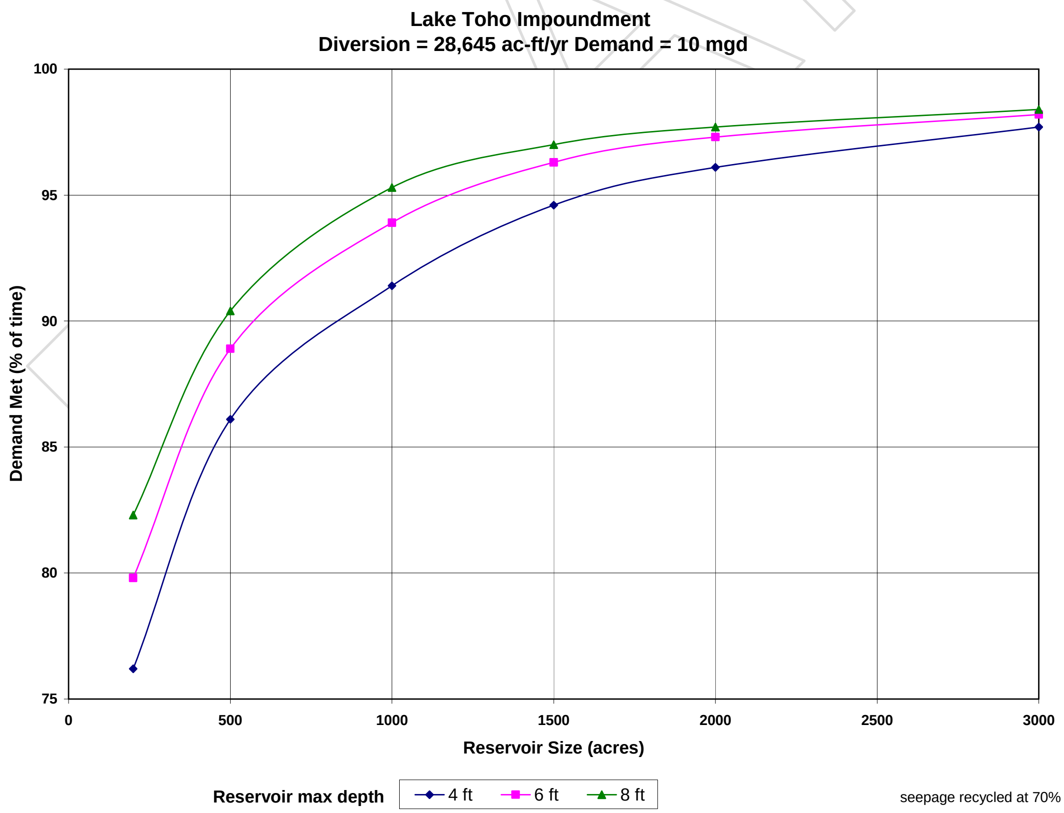

Figure 5. Demand Level Met (percent of time) for a 10 MGD Capacity Treatment Plant.

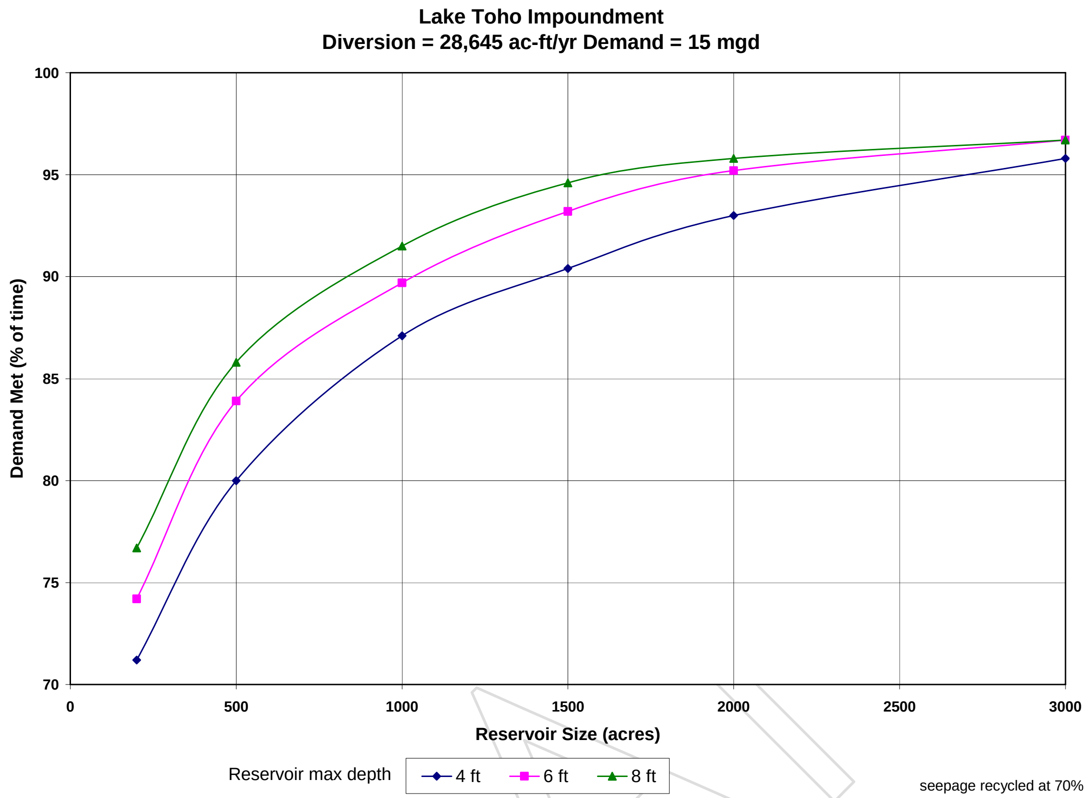

Figure 6. Demand Level Met (percent of time) for a 15 MGD Capacity Treatment Plant.

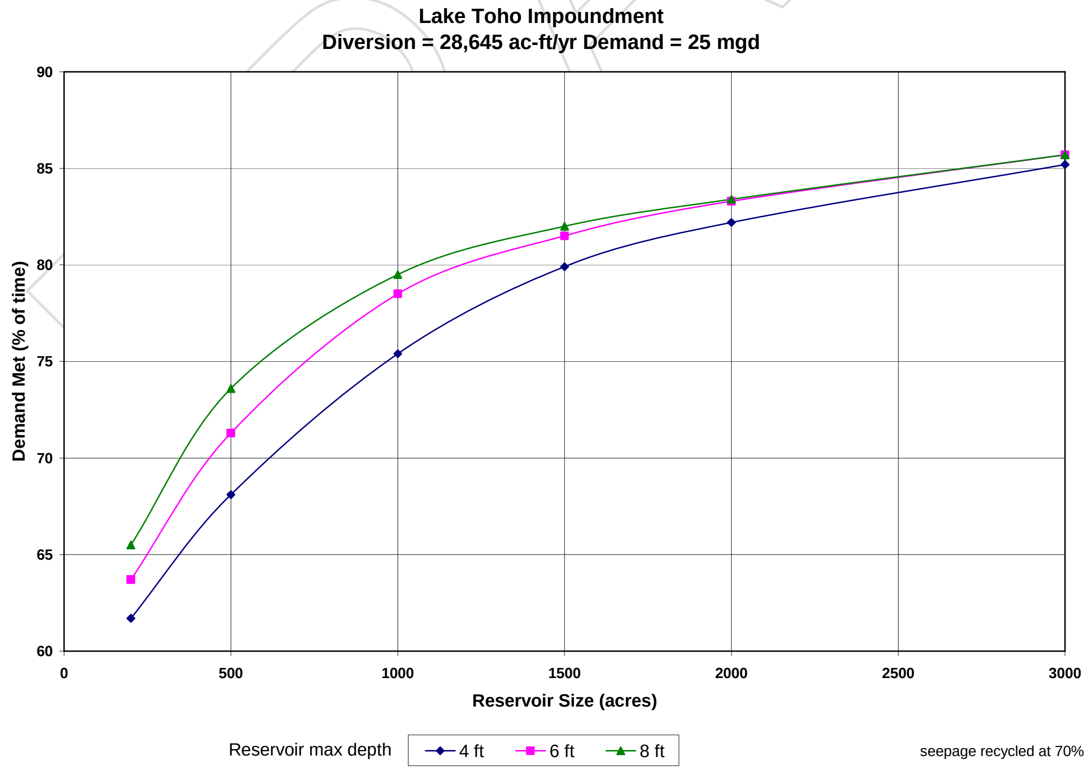

Figure 7. Demand Level Met (percent of time) for a 25 MGD Capacity Treatment Plant.

Next, for every pair of impoundment size and depth and its corresponding water treatment plant capacity (equaled to the demand level met), cost curves for planning level total project cost and cost per 1,000 gallons of treated water were developed. Due to the project's conceptual level design, the actual estimates of the cost cannot be determined until detailed design plans are prepared.

For cost estimation purposes, the impoundment is assumed to be a square shape, and its levee height is determined as follows: for a 4-foot deep impoundment, the levee height is 7.5 feet, for a 6-foot deep impoundment, the levee height is 11 feet and for an 8-foot deep impoundment, it is 17 feet. The seepage return pump is sized based on the impoundment seepage rate when it is half full. The impoundment inflow and outflow pump stations are sized according to the maximum available flow from Lake Toho over the period of record and the demand level met for each alternative, respectively. The cost estimates for seepage control facilities (except for seepage control pumps) are incorporated in the cost of levee construction. The land costs for the impoundment are based on the recent sales of agricultural land in the general area, which run between \$2,000 and \$6,000 per acre for the period between 2002 and 2005. The cost of \$5,000 per acre is used in the cost analysis. Capital cost estimates provided by B. Conlon, PB Water and R. Regalado, MSA in *Cost Estimate Peer Review Report*, *Microfiltration Supplemental Technology Demonstration Project*, were used to estimate the cost for the ultrafiltration based water treatment plant with ZENON UF membranes.

Figure 8 through **Figure 10** show the planning level total cost to design and build the impoundment and water treatment plant facilities as a function of the impoundment size and depth and the treatment plant capacity. **Figure 11** through **Figure 13** show the unit costs (cost per 1,000 gallons of treated water) for different impoundment sizes and water treatment plant capacities.

Figure 8. Planning Level Costs for a 10 MGD Water Treatment Plant/Impoundment.

Figure 9. Planning Level Costs for a 15 MGD Water Treatment Plant/Impoundment.

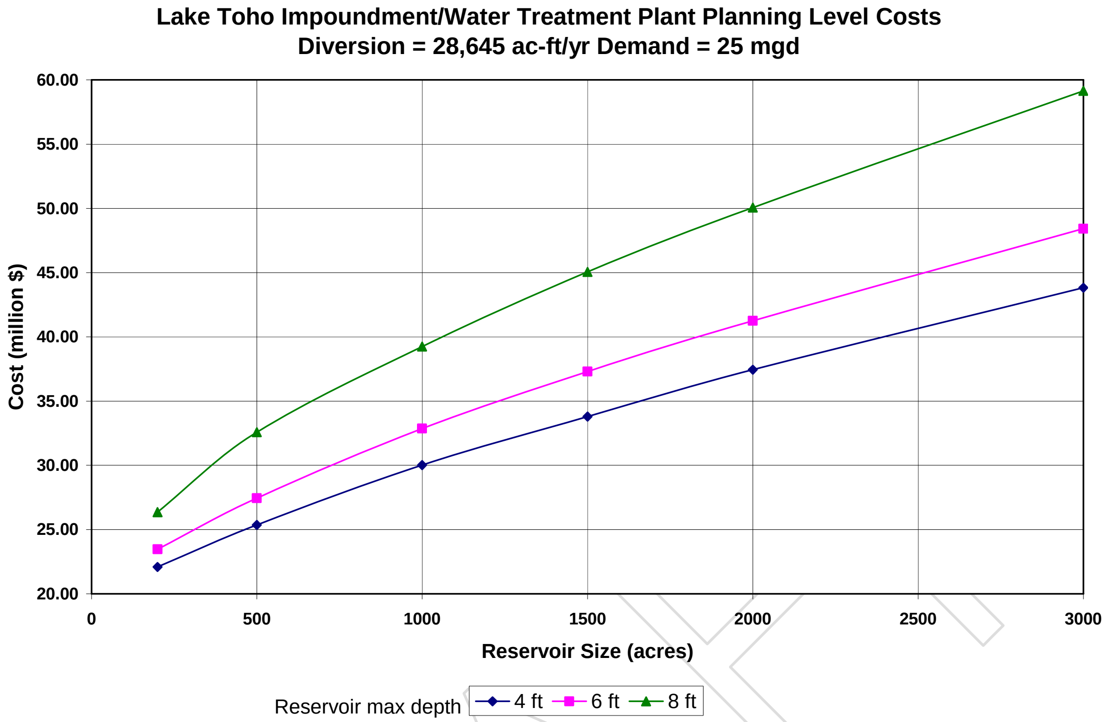

Figure 10. Planning Level Costs for a 25 MGD Water Treatment Plant/Impoundment.

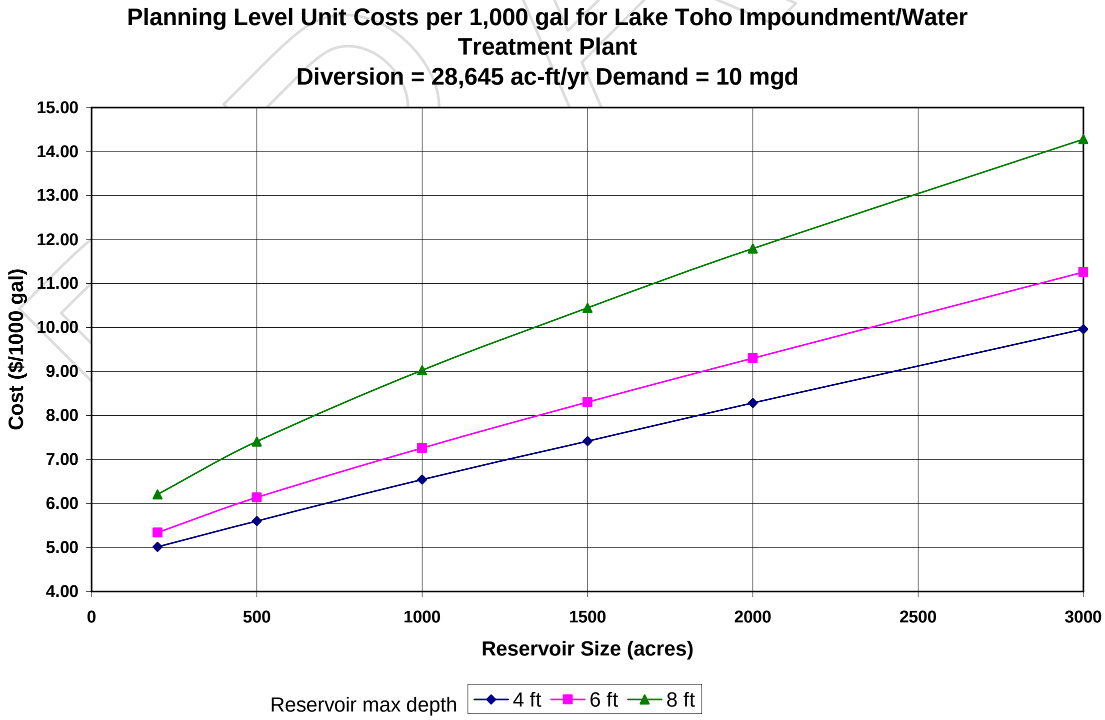

Figure 11. Planning Level Unit Costs per 1,000 gallons for a 10 MGD Water Treatment Plant/Impoundment.

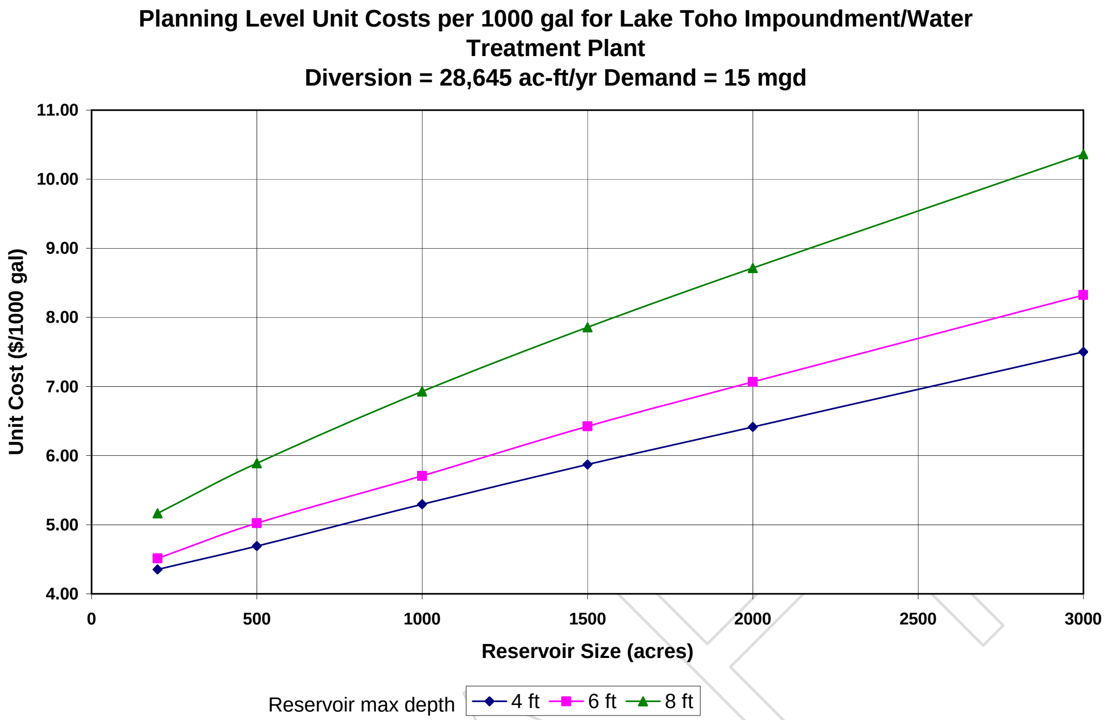

Figure 12. Planning Level Unit Costs per 1,000 gallons for a 15 MGD Water Treatment Plant/Impoundment.

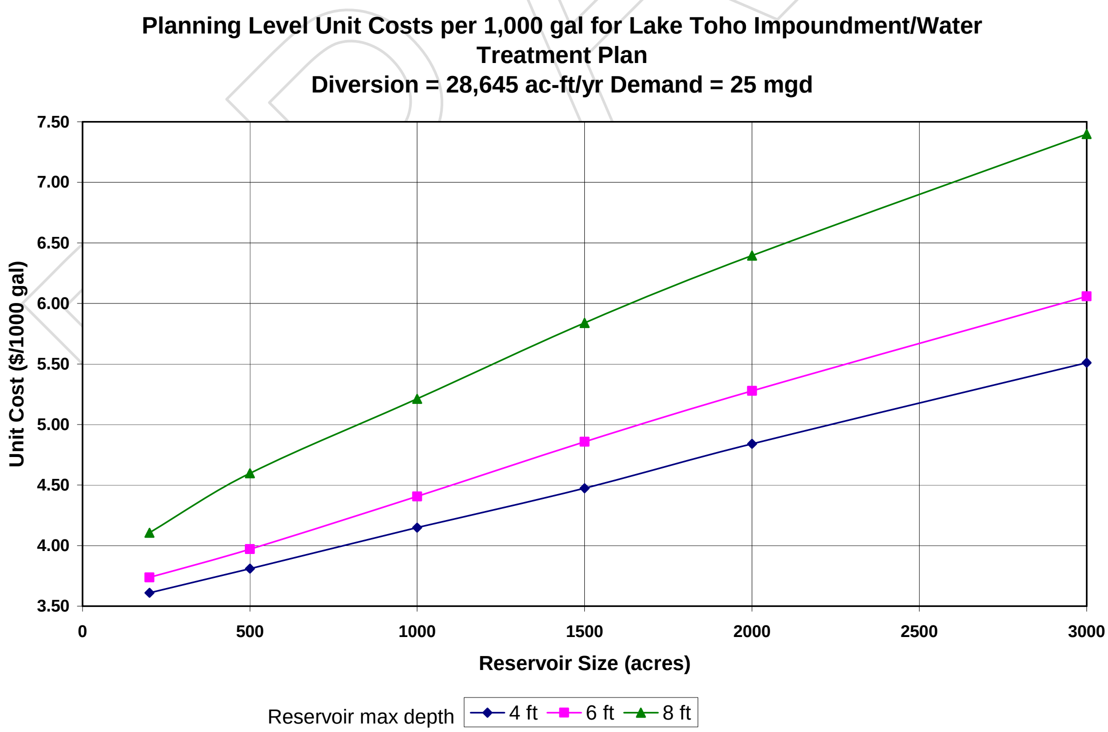

Figure 13. Planning Level Unit Costs per 1,000 gallons for a 25 MGD Water Treatment Plant/Impoundment.

In order to decide, for a given treatment plant capacity, which combination of the impoundment size and depth provides the most cost-efficient alternative, the unit costs should be compared first. As an example, for a 10 MGD plant, a 500-acre 8-foot deep, 1,000-acre 6-foot deep and 1,500-acre 4-foot deep impoundments all provide about the same cost-efficiency (see **Figure 11**). Next, the demand level met for the selected alternatives should be examined. In the previous example, a 500-acre impoundment provides the required inflow to the water treatment plant 90 percent of time, whereas the other two alternatives provide the required flow 94 percent of time (see **Figure 5**).

Table 1 provides, for each water treatment plant capacity, a summary planning level cost estimates for the alternatives that were selected as most cost-efficient. It should be noted that for each plant capacity a 1,000-acre 6-foot deep or a 1,500-acre 4-foot deep impoundments provide the same cost-efficiency level, e.g. the cost per 1,000 gallons of treated water is practically identical (see the cost curves, **Figure 11** through **Figure 13**). **Table 1** provides costs for a 1,000-acre 6-foot deep impoundment option.

Table 1. Planning Level Cost Estimates for an Impoundment/Water Treatment Plant Alternative[a].

System Component	Demand Level 10 MGD Reliability 93.9 %	Demand Level 15 MGD Reliability 89.7 %	Demand Level 25 MGD Reliability 78.5 %
Inflow Pump Station[b]	$1,010,000	$1,010,000	$1,010,000
Outflow Pump Station	$323,000	$423,000	$578,000
Seepage Control Pump	$500,000	$434,000	$350,000
Levees	$4,270,000	$4,270,000	$4,270,000
Water Treatment Plant Capital Cost	$4,780,000	$6,210,000	$8,150,000
Effluent Pump Station	$323,000	$423,000	$578,000
Water Treatment Plant Installation and Construction, 50% of Capital Costs[c]	$2,551,500	$3,316,500	$4,364,000
Project Implementation, 20% of Capital Costs (impoundment and water treatment plant)	$2,241,200	$2,554,000	$2,987,200
Subtotal Construction Costs	$15,998,700	$18,640,500	$22,287,200
Contingency at 25%	$3,999,700	$4,660,100	$5,571,800
Land	$5,000,000	$5,000,000	$5,000,000
Total Cost	$24,998,400	$28,300,600	$32,859,000
Cost per 1,000 gal.	$7.26	$5.71	$4.41
Annual O&M at 2–3% of Construction Costs	$353,500	$369,200	$403,900

a. Based on Lake Toho available diversion volume of 28,645 acre-feet per year.
b. A second pump station will be required depending on the distance from the Lake to the impoundment.
c. A 10% allowance is included for the canal construction connecting the Lake and the impoundment, and a possible additional pump (see b).

Due to economies of scale, the cost per 1,000 gallons of treated water (**Table 1**) goes down with the increase of the demand level. The cost is $7.26 per 1,000 gallons of treated water for the demand level of 10 MGD and only $4.41 per 1,000 gallons for the demand level of 25 MGD. However, it should be emphasized that for the demand level of 10 MGD the demand is met 94 percent of time, whereas for the demand level of 25 MGD it is met only 79 percent of time. As a comparison, without the proposed impoundment, Lake Toho would be able to meet the water treatment plant demand only 66 percent of time for a 10 MGD plant capacity and a mere 53 percent of time for a 25 MGD plant capacity (*J. Cai 2005*). On the average, there is a 26 percent increase in the ability of the surface water treatment plant to meet the demand with the inclusion of an impoundment option.

In order to improve the impoundment performance and the water treatment plant reliability for the demand levels of 15 and 25 MGD and possibly higher, a revised Lake Toho water withdrawal scenario that takes into account not only the Lake's regulation schedule, but also its historical water levels was developed (*J. Cai 2005*). The new time series provided a 34 percent increase in water available for diversion into the impoundment.

Figure 14 through **Figure 16** show the demand level met, by volume, as a function of the impoundment size for the 15, 25 and 30 MGD capacity water treatment plants using the new time series of available water. **Figure 17** through **Figure 19** show the same relationship with the demand level met expressed as percent of time. The results of the impoundment performance show a two to five percent increase in the demand volume met for the 15 MGD level of demand (**Figure 3** and **Figure 14**), and a much improved impoundment performance for the 25 MGD level of demand (**Figure 4** and **Figure 15**). There is, on average, a 12 percent increase in water treatment plant reliability using the new Lake Toho available water time series for the demand level of 25 MGD (see **Figure 7** and **Figure 18**). In addition, the new time series of available water allows meeting the 30 MGD level of demand within a range of 25.0 MGD and 30.8 MGD, or between 73.8 and 91.6 percent of time, respectively (**Figure 16** and **Figure 19**). The smaller number corresponds to a 200-acre 4-foot deep impoundment and the bigger number corresponds to a 3,000-acre 8-foot deep impoundment.

Figure 20 through **Figure 22** show planning level total cost for the impoundment/water treatment plant as a function of the impoundment size and depth and the treatment plant capacity using new available water time series for impoundment sizing. **Figure 23** through **Figure 25** show the unit costs (cost per 1,000 gallons of treated water) for different impoundment sizes and water treatment plant capacities.

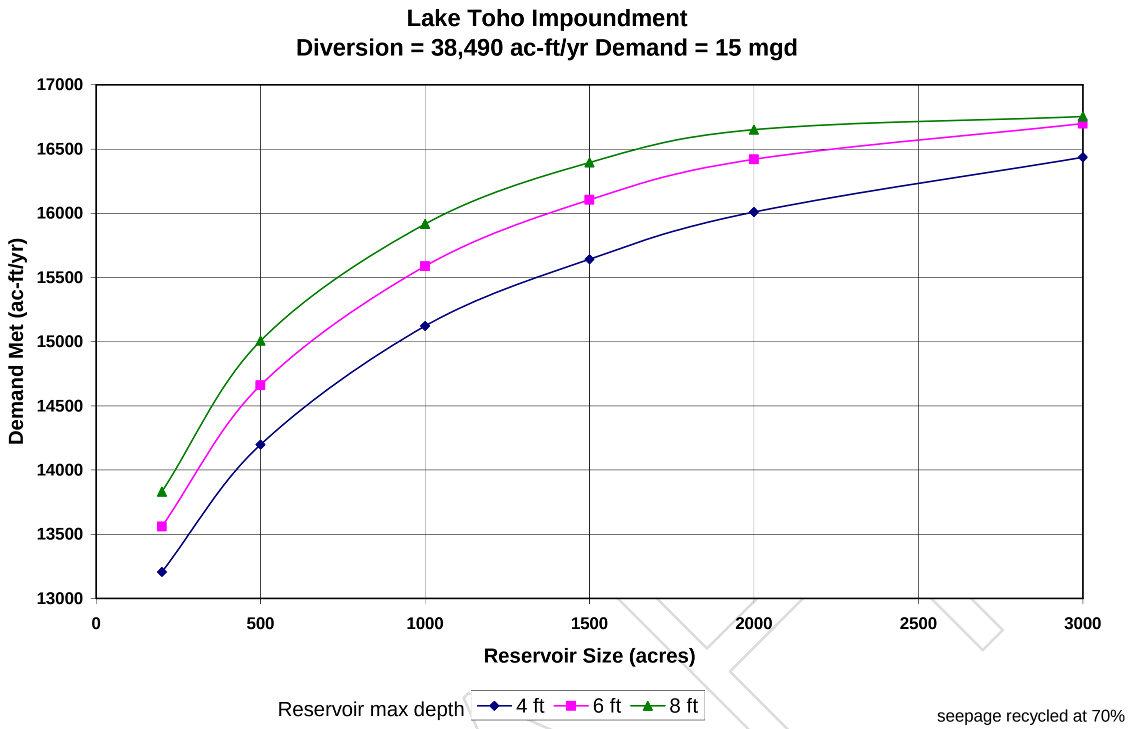

Figure 14. Demand Level Met (by volume) for a 15 MGD Capacity Treatment Plant.

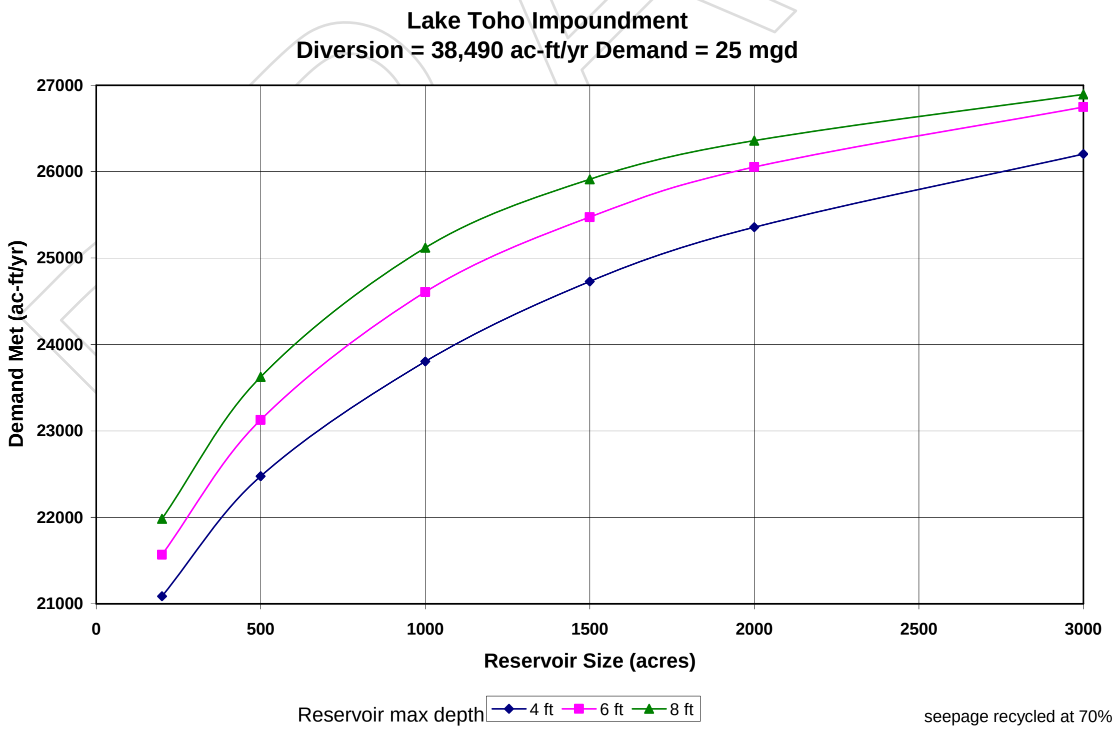

Figure 15. Demand Level Met (by volume) for a 25 MGD Capacity Treatment Plant.

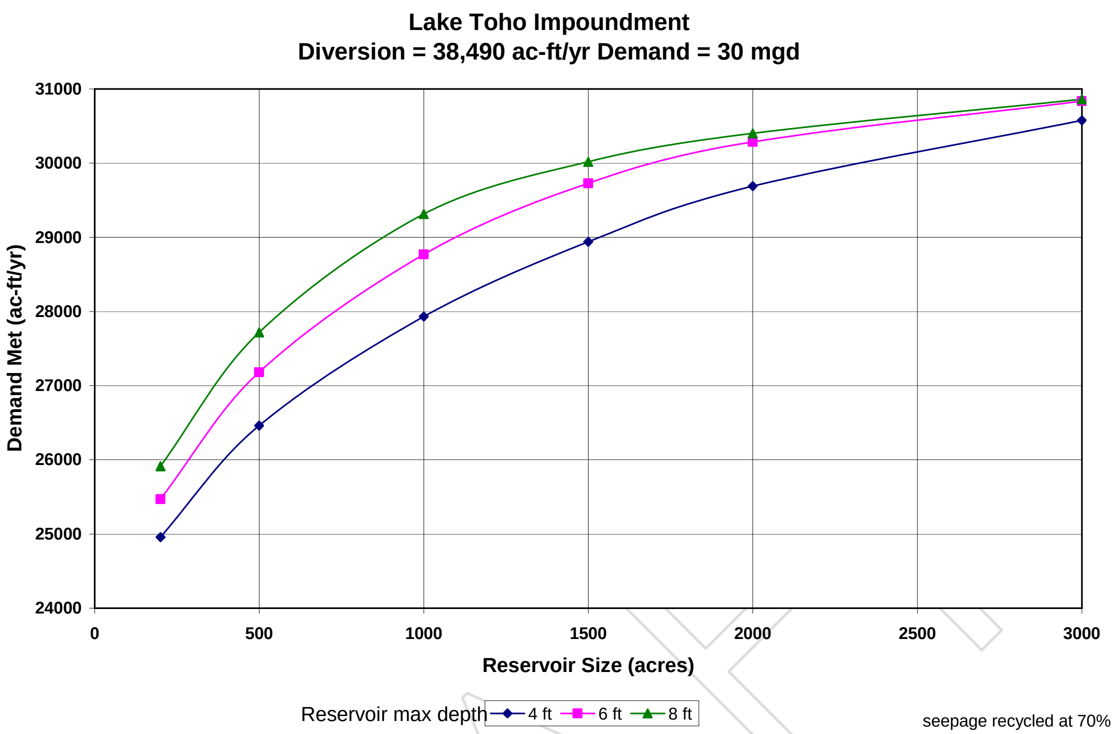

Figure 16. Demand Level Met (by volume) for a 30 MGD Capacity Treatment Plant.

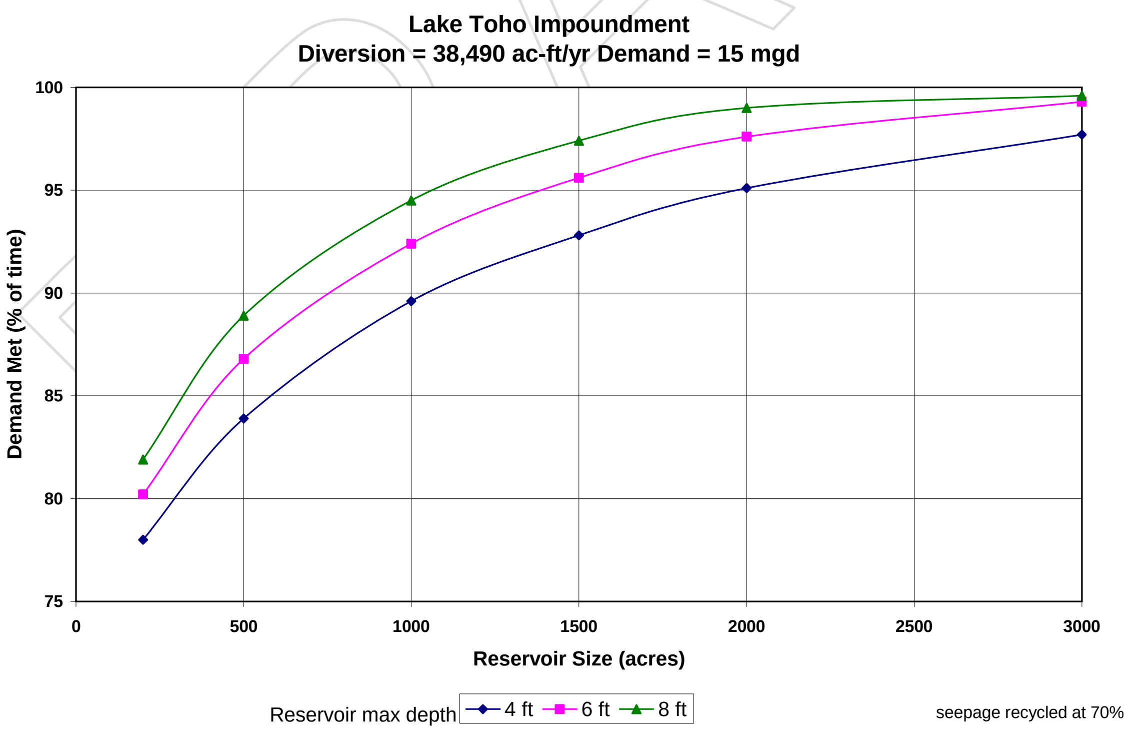

Figure 17. Demand Level Met (percent of time) for a 15 MGD Capacity Treatment Plant.

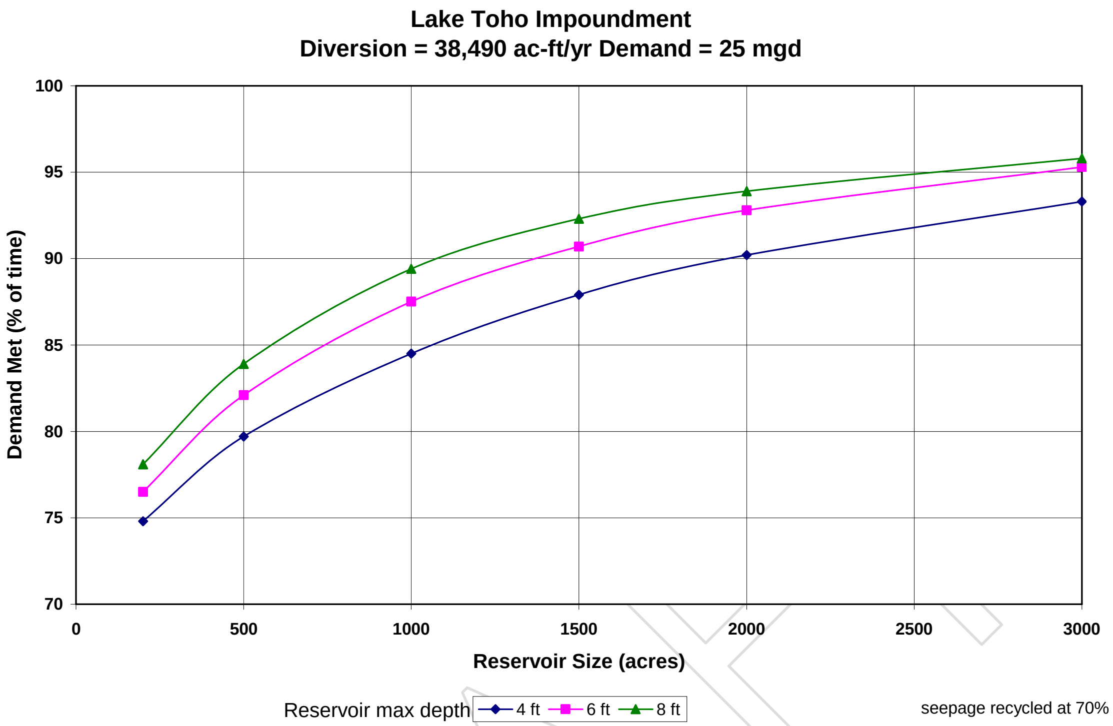

Figure 18. Demand Level Met (percent of time) for a 25 MGD Capacity Treatment Plant.

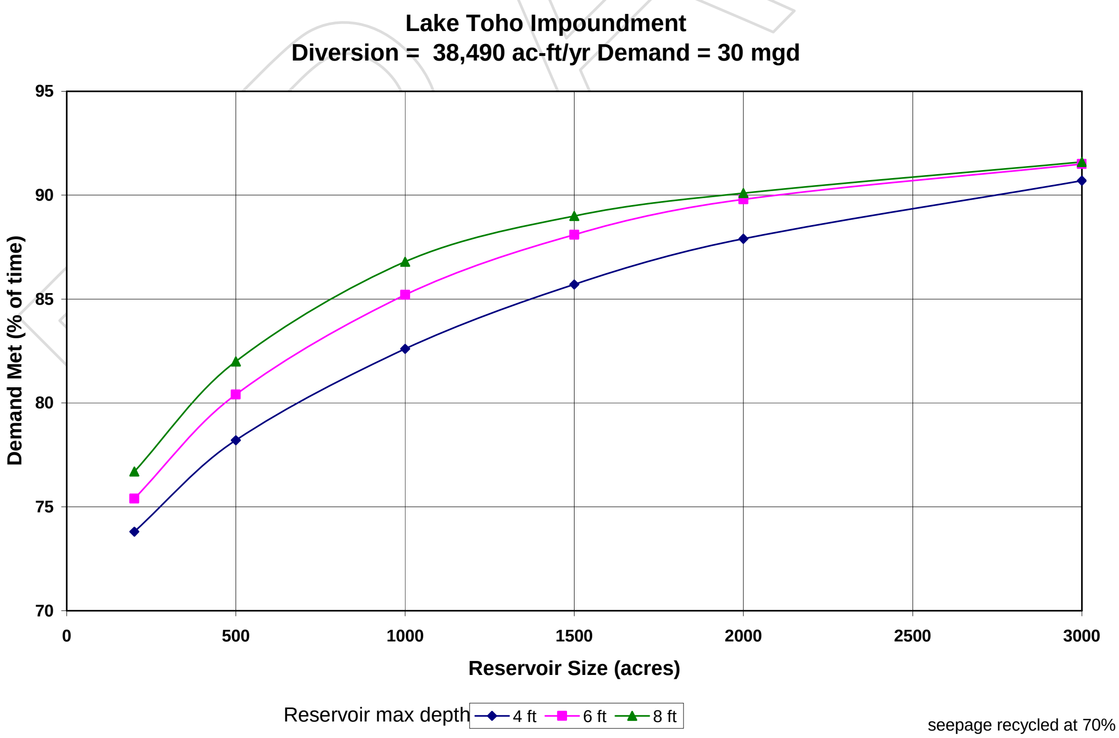

Figure 19. Demand Level Met (percent of time) for a 30 MGD Capacity Treatment Plant.

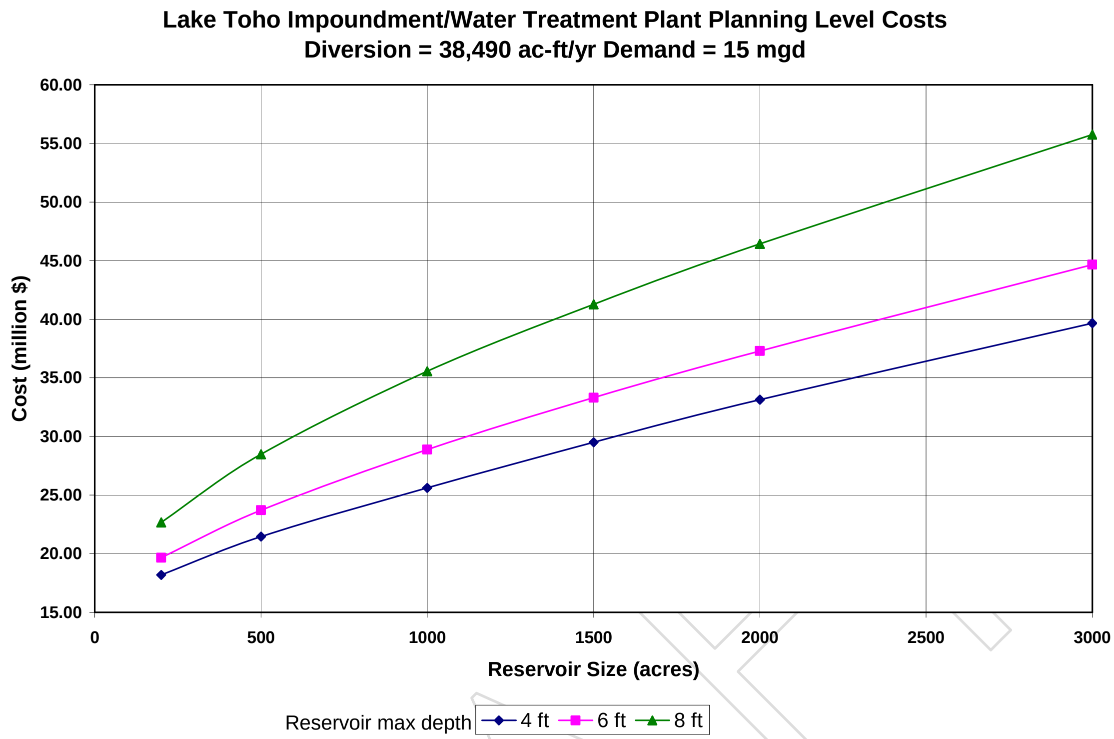

Figure 20. Planning Level Costs for a 15 MGD Water Treatment Plant/Impoundment.

Figure 21. Planning Level Costs for a 25 MGD Water Treatment Plant/Impoundment.

Figure 22. Planning Level Costs for a 30 MGD Water Treatment Plant/Impoundment.

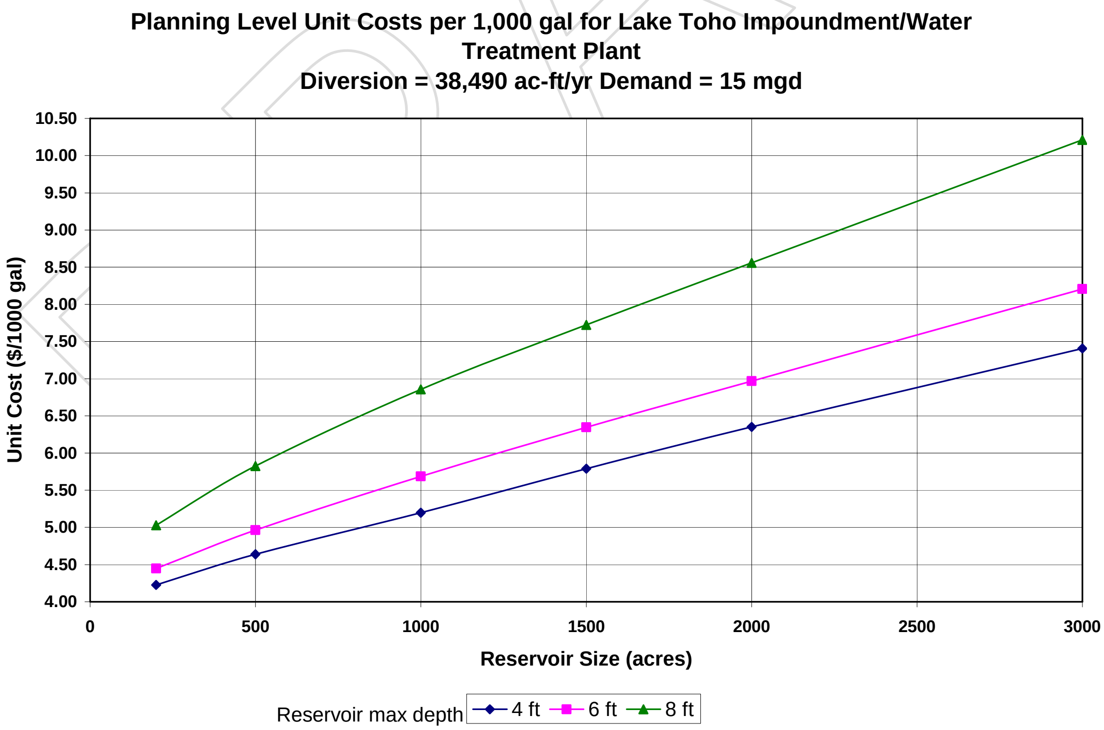

Figure 23. Planning Level Unit Costs per 1,000 gallons for a 15 MGD Water Treatment Plant/Impoundment.

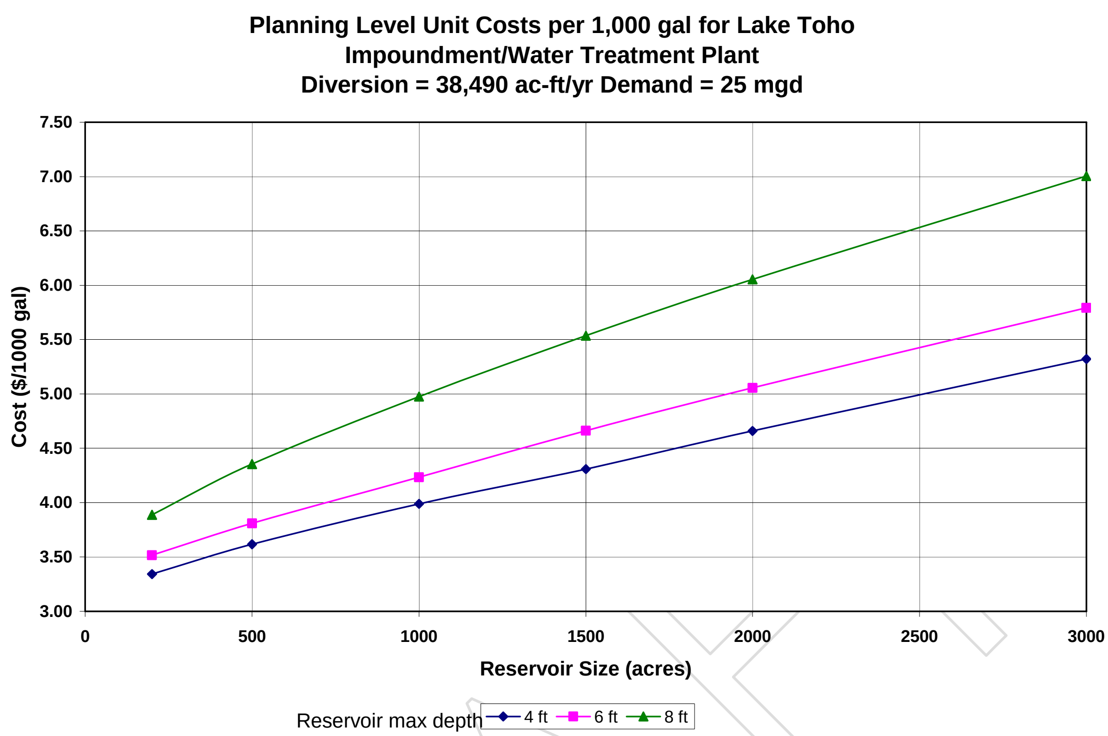

Figure 24. Planning Level Unit Costs per 1,000 gallons for a 25 MGD Water Treatment Plant/Impoundment.

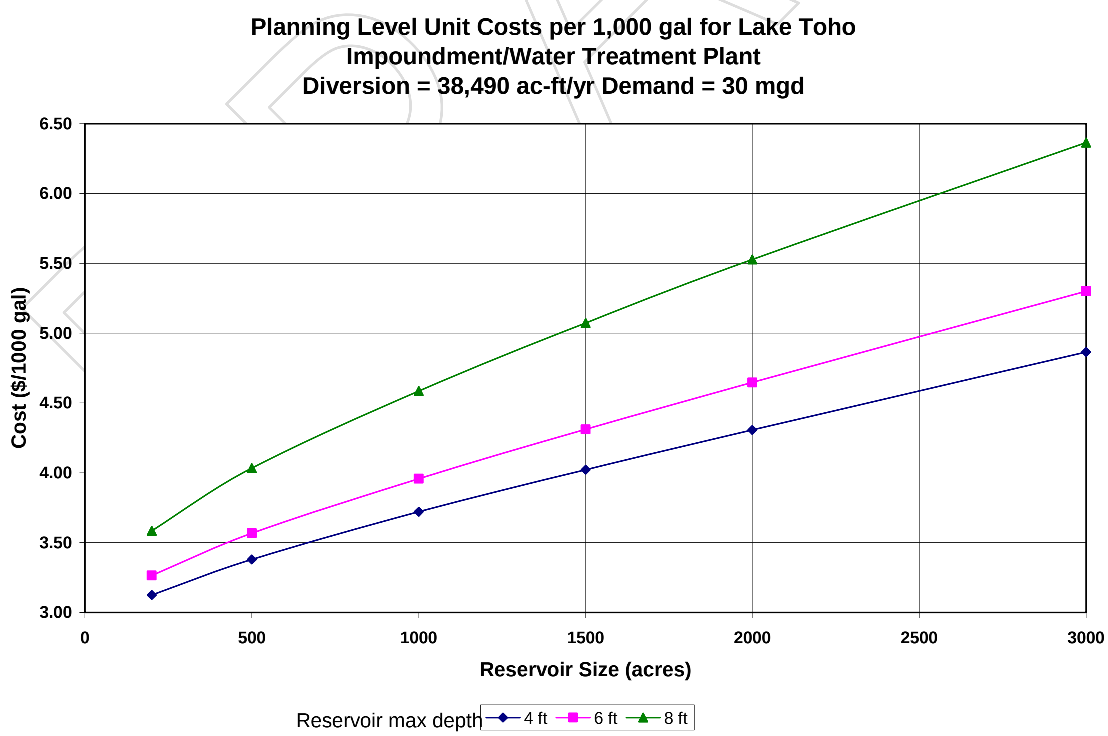

Figure 25. Planning Level Unit Costs per 1,000 gallons for a 30 MGD Water Treatment Plant/Impoundment.

Table 2 provides summary planning level cost estimates for the alternatives that were selected as most cost-efficient: 1,500-acre 6-foot deep impoundments for all three treatment plant capacities.

Table 2. Planning Level Cost Estimates for an Impoundment/Water Treatment Plant Alternative[a].

System Component	Demand Level 15 MGD Reliability 95.6 %	Demand Level 25 MGD Reliability 90.7 %	Demand Level 30 MGD Reliability 88.1 %
Inflow Pump Station[b]	$1,010,000	$1,010,000	$1,010,000
Outflow Pump Station	$423,000	$578,000	$650,000
Seepage Control Pump	$610,000	$540,000	$490,000
Levees	$5,230,000	$5,230,000	$5,230,000
Water Treatment Plant Capital Cost	$6,590,000	$8,910,000	$10,270,000
Effluent Pump Station	$423,000	$578,000	$650,000
Water Treatment Plant Installation and Construction, 50% of Capital Costs[c]	$3,510,000	$4,740,000	$5,460,000
Project Implementation, 20% of Capital Costs (impoundment and water treatment plant)	$2,860,000	$3,370,000	$3,660,000
Subtotal Construction Costs	$20,650,000	$24,950,000	$27,420,000
Contingency at 25%	$5,160,000	$6,240,000	$6,850,000
Land	$7,500,000	$7,500,000	$7,500,000
Total Cost	$33,310,000	$38,690,000	$41,770,000
Cost per 1,000 gal.	$6.35	$4.66	$4.31
Annual O&M at 2-3% of Construction Costs	$408,300	$451,600	$487,100

a. Based on Lake Toho available diversion volume of 38,490 acre-feet per year.
b. A second pump station will be required depending on the distance from the Lake to the impoundment.
c. A 10% allowance is included for the canal construction connecting the Lake and the impoundment, and a possible additional pump (see b).

TECHNICAL MEMORANDUM

Reservoir Sizing in the Upper Kissimmee River Basin

One of the possible alternatives in meeting the growing potable water demand of the area's population is the use of basin stormwater runoff. This work summarizes results of sizing an aboveground impoundment to divert and store the surface water from Lake Tohopekaliga (Lake Toho) when it is above or within the allowable range below its regulation schedule, and subsequent use of the stored water as a source influent to a water treatment plant. A water budget simulation model was developed and run on a daily basis to size an impoundment based on a 32-year period of record of available diversion from Lake Toho.

The following describes the hydrologic variables and assumptions used in the model simulation.

- Rainfall data used in the model comes from the rainfall dataset used in running the Upper Kissimmee Chain of Lakes Routing Model (UKISS Model) corresponding to the Lake Toho subbasin.
- Evapotranspiration data used in the model is a pan evapotranspiration for an open water land use recently updated for the central Florida region by District staff.
- Seepage rate loss from the impoundment is assumed to be two cfs per mile of the impoundment levee per one foot of head difference between the impoundment and the seepage perimeter canal, selected based on the hydrogeologic characteristics of the basin and literature research. Seepage is assumed to be recycled at 70 percent rate by the seepage pumps installed in the seepage perimeter canal.
- Time series of daily flows available for diversion into the impoundment was calculated by comparing the Lake stage with its regulation schedule. For the detailed water availability methodology refer to the technical memorandum entitled, *A Preliminary Evaluation of Available Surface Water in East Lake Toho and Lake Toho* (Cai 2005). Two scenarios with the average annual volume of Lake Toho water available for diversion of 28,645 and 38,490 acre-feet were analyzed.
- The demand time series (daily releases from the impoundment) varied between 10 and 25 MGD for the available diversion of 28,645 acre-feet per year and between 15 and 30 MGD for the available diversion of 38,490 acre-feet per year.

Several model runs using different impoundment sizes and demand levels were simulated to evaluate the performance of the impoundment. A summary of all runs is provided. The summary shows impoundment size and the maximum water depth, amount of water available, but not diverted into the impoundment due to it being full (spillover), demands met, average impoundment depth, percent of time the impoundment is 90, 75 and 50 percent full and seepage losses for the 32-year simulation period (**Table 3** through **Table 8**). Six different impoundment sizes (200, 500, 1,000, 1,500, 2,000 and 3,000 acres) and three different maximum impoundment depths (4, 6 and 8 feet) were simulated.

Table 3. Summary Reservoir Performance (Diversion = 28,645 acre-feet per year). Demand = 10 MGD, Seepage rate = 2 cfs/mi/ft of head (70% recycled).

Reservoir Depth, ft	Reservoir Area, acres	Spillover ac-ft/yr	Demand Met			Avg Res Stage, ft	Res @ 90% Capacity, % of time	Res @ 75% Capacity, % of time	Res @ 50% Capacity, % of time	Seepage @ Avg Stage, cfs
			ac-ft/yr	mgd	% of time					
4	200	17943	8813	7.87	76.2	2.47	55.7	58.3	63.5	11.07
4	500	15564	9777	8.73	86.1	2.67	53.0	58.6	68.1	18.90
4	1000	13137	10311	9.21	91.4	2.85	51.0	59.8	74.2	28.50
4	1500	11237	10621	9.48	94.6	2.91	49.2	60.5	76.9	35.62
4	2000	9694	10787	9.63	96.1	2.94	47.7	61.2	77.6	41.57
4	3000	7208	10959	9.78	97.7	2.96	44.2	61.9	78.3	51.27
6	200	16514	9148	8.17	79.8	3.80	54.1	57.9	64.5	17.02
6	500	13440	10042	8.97	88.9	4.11	50.4	57.7	70.0	29.10
6	1000	10272	10563	9.43	93.9	4.28	46.9	58.2	75.7	42.80
6	1500	7962	10809	9.65	96.3	4.32	43.6	57.6	76.6	52.88
6	2000	6166	10923	9.75	97.3	4.33	40.0	57.5	76.8	61.23
6	3000	3677	11012	9.83	98.2	4.22	32.9	51.9	77.6	73.09
8	200	15158	9406	8.40	82.3	5.14	52.8	57.2	65.0	23.03
8	500	11470	10197	9.10	90.4	5.50	47.9	56.7	71.0	38.94
8	1000	7673	10709	9.56	95.3	5.62	42.4	54.8	74.9	56.20
8	1500	5138	10891	9.72	97.0	5.59	35.9	53.0	75.2	68.42
8	2000	3384	10963	9.79	97.7	5.46	30.4	48.4	75.4	77.20
8	3000	1354	11035	9.85	98.4	5.05	19.0	37.6	70.3	87.47

Table 4. Summary Reservoir Performance (Diversion = 28,645 acre-feet per year). Demand = 15 MGD, Seepage rate = 2 cfs/mi/ft of head (70% recycled).

Reservoir Depth, ft	Reservoir Area, acres	Spillover ac-ft/yr	Demand Met			Avg Res Stage, ft	Res @ 90% Capacity, % of time	Res @ 75% Capacity, % of time	Res @ 50% Capacity, % of time	Seepage @ Avg Stage, cfs
			ac-ft/yr	mgd	% of time					
4	200	14577	12416	11.09	71.2	2.22	51.2	54.4	58.1	9.95
4	500	12057	13798	12.32	80.0	2.37	47.5	52.4	60.0	16.78
4	1000	9468	14842	13.25	87.1	2.50	43.3	50.9	63.5	25.00
4	1500	7674	15334	13.69	90.4	2.56	40.3	49.8	67.3	31.33
4	2000	6233	15712	14.03	93.0	2.58	37.3	49.2	68.0	36.48
4	3000	4097	16137	14.41	95.8	2.56	31.4	45.9	68.2	44.34
6	200	13148	12869	11.49	74.2	3.40	49.7	53.4	58.4	15.23
6	500	9880	14357	12.82	83.9	3.60	44.1	50.1	60.6	25.49
6	1000	6804	15220	13.59	89.7	3.74	38.1	47.7	65.1	37.40
6	1500	4698	15742	14.06	93.2	3.72	31.7	44.7	65.3	45.53
6	2000	3232	16057	14.34	95.2	3.64	26.8	40.5	64.5	51.47
6	3000	1556	16280	14.54	96.7	3.42	18.6	32.1	60.5	59.23
8	200	11807	13237	11.82	76.7	4.59	47.9	52.0	58.6	20.56
8	500	7995	14651	13.08	85.8	4.81	40.7	48.3	60.6	34.05
8	1000	4521	15493	13.83	91.5	4.83	31.0	43.1	63.5	48.30
8	1500	2456	15963	14.25	94.6	4.64	23.3	36.6	60.9	56.79
8	2000	1359	16152	14.42	95.8	4.36	16.9	29.4	56.3	61.65
8	3000	411	16286	14.54	96.7	3.85	10.8	18.0	45.5	66.68

Table 5. Summary Reservoir Performance (Diversion = 28,645 acre-feet per year).
Demand = 25 MGD, Seepage rate = 2 cfs/mi/ft of head (70% recycled).

Reservoir Depth, ft	Reservoir Area, acres	Spillover ac-ft/yr	Demand Met			Avg Res Stage, ft	Res @ 90% Capacity, % of time	Res @ 75% Capacity, % of time	Res @ 50% Capacity, % of time	Seepage @ Avg Stage, cfs
			ac-ft/yr	mgd	% of time					
4	200	8587	18774	16.76	61.7	1.82	34.8	45.6	50.3	8.15
4	500	6199	20426	18.24	68.1	1.89	33.7	40.8	49.4	13.38
4	1000	3753	22199	19.82	75.4	1.82	25.8	34.2	46.0	18.20
4	1500	2331	23186	20.70	79.9	1.74	19.8	28.5	42.8	21.30
4	2000	1568	23731	21.19	82.2	1.64	15.8	23.6	38.3	23.19
4	3000	749	24405	21.79	85.2	1.45	11.6	17.3	30.9	25.11
6	200	7301	19265	17.20	63.7	2.79	35.9	44.1	49.9	12.50
6	500	4269	21205	18.93	71.3	2.76	28.4	36.7	47.1	19.54
6	1000	1787	22878	20.43	78.5	2.50	17.4	27.0	40.5	25.00
6	1500	834	23556	21.03	81.5	2.24	11.8	18.8	33.8	27.42
6	2000	369	23985	21.42	83.3	2.02	8.4	15.0	27.9	28.56
6	3000	92	24523	21.90	85.7	1.68	4.8	9.7	20.2	29.10
8	200	6122	19692	17.58	65.5	3.70	33.6	41.1	49.1	16.58
8	500	2772	21742	19.41	73.6	3.49	23.1	31.1	44.3	24.71
8	1000	734	23103	20.63	79.5	2.95	10.9	18.4	33.8	29.50
8	1500	148	23674	21.14	82.0	2.50	5.7	11.6	25.4	30.60
8	2000	5	24018	21.44	83.4	2.16	3.2	7.2	19.4	30.54
8	3000	0	24527	21.90	85.7	1.71	0.0	2.4	12.6	29.62

Table 6. Summary Reservoir Performance (Diversion = 38,490 acre-feet per year). Demand = 15 MGD, Seepage rate = 2 cfs/mi/ft of head (70% recycled).

Reservoir Depth, ft	Reservoir Area, acres	Spillover ac-ft/yr	Demand Met			Avg Res Stage, ft	Res @ 90% Capacity, % of time	Res @ 75% Capacity, % of time	Res @ 50% Capacity, % of time	Seepage @ Avg Stage, cfs
			ac-ft/yr	mgd	% of time					
4	200	23196	13205	11.79	78.0	2.72	66.1	68.6	72.0	12.19
4	500	20768	14197	12.68	83.9	2.90	64.8	68.8	74.4	20.53
4	1000	17984	15121	13.50	89.6	3.01	62.7	69.4	76.9	30.10
4	1500	15813	15642	13.97	92.8	3.05	60.9	68.4	78.3	37.33
4	2000	13940	16009	14.29	95.1	3.07	58.8	67.9	78.8	43.41
4	3000	10771	16436	14.68	97.7	3.09	55.8	66.2	80.1	53.52
6	200	21636	13560	12.11	80.2	4.19	65.6	68.4	72.5	18.77
6	500	18325	14661	13.09	86.8	4.43	63.3	68.9	75.6	31.36
6	1000	14691	15587	13.92	92.4	4.54	59.6	67.9	77.5	45.40
6	1500	11953	16104	14.38	95.6	4.57	56.4	66.5	78.4	55.94
6	2000	9704	16421	14.66	97.6	4.57	53.4	65.1	79.2	64.62
6	3000	6284	16698	14.91	99.3	4.55	48.9	62.2	79.1	78.81
8	200	20155	13831	12.35	81.9	5.68	64.7	68.2	73.1	25.45
8	500	16001	15007	13.40	88.9	5.94	61.2	68.0	76.0	42.06
8	1000	11624	15916	14.21	94.5	6.02	55.8	65.6	77.3	60.20
8	1500	8454	16395	14.64	97.4	6.00	51.1	62.9	78.1	73.44
8	2000	6053	16651	14.87	99.0	5.95	47.0	60.5	77.5	84.13
8	3000	2754	16754	14.96	99.6	5.8	36.8	55.7	77.4	100.46

Table 7. Summary Reservoir Performance (Diversion = 38,490 acre-feet per year). Demand = 25 MGD, Seepage rate = 2 cfs/mi/ft of head (70% recycled).

Reservoir Depth, ft	Reservoir Area, acres	Spillover ac-ft/yr	Demand Met			Avg Res Stage, ft	Res @ 90% Capacity, % of time	Res @ 75% Capacity, % of time	Res @ 50% Capacity, % of time	Seepage @ Avg Stage, cfs
			ac-ft/yr	mgd	% of time					
4	200	15505	21086	18.83	74.8	2.50	63.0	65.9	68.7	11.20
4	500	12853	22475	20.07	79.7	2.67	59.4	63.7	69.4	18.90
4	1000	10124	23805	21.25	84.5	2.70	53.0	60.2	70.5	27.00
4	1500	8073	24729	22.08	87.9	2.68	48.4	57.0	69.1	32.80
4	2000	6420	25358	22.64	90.2	2.65	44.1	55.6	68.0	37.47
4	3000	3981	26205	23.40	93.3	2.58	38.2	50.5	66.2	44.69
6	200	13902	21567	19.26	76.5	3.88	61.2	64.9	68.7	17.38
6	500	10441	23128	20.65	82.1	4.02	54.7	61.5	69.7	28.46
6	1000	6986	24609	21.97	87.5	3.96	46.6	56.1	68.1	39.60
6	1500	4630	25475	22.75	90.7	3.87	39.3	52.8	66.2	47.37
6	2000	2943	26055	23.26	92.8	3.76	33.6	47.5	65.1	53.17
6	3000	1067	26750	23.88	95.3	3.44	21.0	37.6	60.8	59.58
8	200	12374	21983	19.63	78.1	5.24	59.4	63.8	68.8	23.48
8	500	8291	23625	21.09	83.9	5.30	50.6	57.4	69.2	37.52
8	1000	4323	25121	22.43	89.4	5.12	39.1	51.7	65.9	51.20
8	1500	2031	25911	23.13	92.3	4.85	28.9	43.9	63.8	59.36
8	2000	838	26360	23.54	93.9	4.50	19.3	34.9	59.5	63.63
8	3000	109	26894	24.01	95.8	3.77	6.3	19.5	48.9	65.30

Table 8. Summary Reservoir Performance (Diversion = 38,490 acre-feet per year). Demand = 30 MGD, Seepage rate = 2 cfs/mi/ft of head (70% recycled).

Reservoir Depth, ft	Reservoir Area, acres	Spillover ac-ft/yr	Demand Met			Avg Res Stage, ft	Res @ 90% Capacity, % of time	Res @ 75% Capacity, % of time	Res @ 50% Capacity, % of time	Seepage @ Avg Stage, cfs
			ac-ft/yr	mgd	% of time					
4	200	11740	24958	22.28	73.8	2.38	59.4	62.8	66.8	10.66
4	500	9090	26462	23.63	78.2	2.51	54.3	58.2	65.7	17.77
4	1000	6457	27931	24.94	82.6	2.49	47.3	53.6	63.7	24.90
4	1500	4599	28938	25.84	85.7	2.44	39.6	49.9	63.1	29.87
4	2000	3196	29688	26.51	87.9	2.35	33.3	44.4	61.2	33.23
4	3000	1457	30575	27.30	90.7	2.20	24.2	36.9	57.4	38.10
6	200	10169	25469	22.74	75.4	3.68	56.8	60.9	65.5	16.49
6	500	6792	27180	24.27	80.4	3.73	48.6	54.8	63.6	26.41
6	1000	3613	28770	25.69	85.2	3.58	36.9	48.4	62.1	35.80
6	1500	1776	29727	26.54	88.1	3.34	26.6	39.0	58.9	40.88
6	2000	785	30286	27.04	89.8	3.08	18.7	31.7	52.7	43.55
6	3000	206	30837	27.53	91.5	2.60	8.6	18.5	42.2	45.03
8	200	8694	25913	23.14	76.7	4.94	54.4	58.8	64.9	22.13
8	500	4783	27719	24.75	82.0	4.86	43.3	51.1	62.2	34.41
8	1000	1551	29314	26.17	86.8	4.40	26.2	37.6	58.0	44.00
8	1500	396	30016	26.80	89.0	3.84	13.3	26.4	48.4	47.00
8	2000	75	30401	27.14	90.1	3.35	6.4	15.6	40.1	47.37
8	3000	0	30860	27.55	91.6	2.67	0.0	5.20	24.4	46.24

One of the best indicators of impoundment performance is the volume of spillover, e.g. the amount of water available, but not pumped into the impoundment due to it being full. As a rule, the smaller the impoundment's size and depth, the bigger the spillover. **Figure 26** through **Figure 28** show, for the diversion volume of 28,645 acre-feet/year, the average annual spillover as a function of the impoundment size for the demand level of 10, 15 and 25 MGD, respectively. Each line on the graphs represents an impoundment performance curve with a different maximum impoundment depth.

Figure 29 through **Figure 31** show, for the diversion volume of 28,645 acre-feet/year, the average impoundment depth as a function of the impoundment size for the demand level of 10, 15 and 25 MGD, respectively. For a given impoundment maximum depth, there is a pronounced drop in the impoundment average water levels with the increase of the impoundment size (due to increase in seepage losses) and the demand level.

Figure 32 through **Figure 34** and **Figure 35** through **Figure 37** show the frequency of the impoundment being 90 and 75 percent full, respectively, for the demand level of 10, 15 and 25 MGD, and the diversion volume of 28,645 acre-feet/year. With the exception of a 4-foot deep impoundment for the demand level of 10 MGD, all performance curves show a lower frequency of impoundment being 90 and 75 percent full with the increase of the impoundment size.

Figure 38 through **Figure 49** describe impoundment performance for the demand level of 15, 25 and 30 MGD and the Lake Toho average annual volume available for the diversion of 38,490 acre-feet.

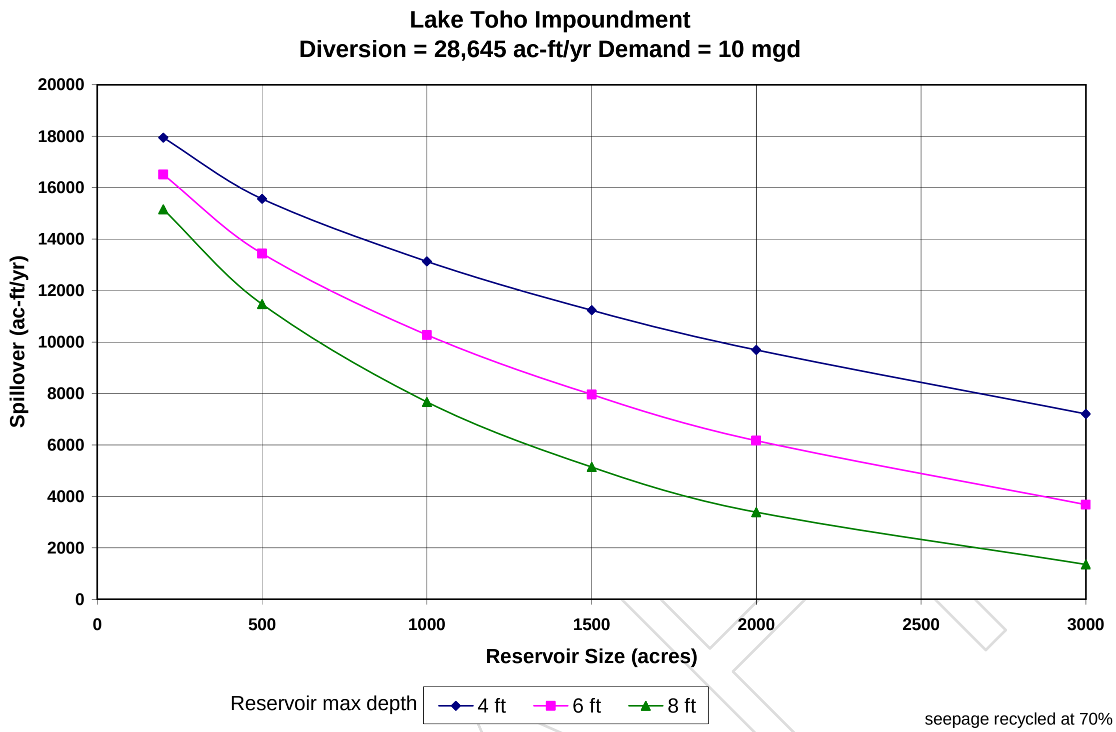

Figure 26. Lake Toho Impoundment Annual Average Spillover for the 10 MGD Demand Level.

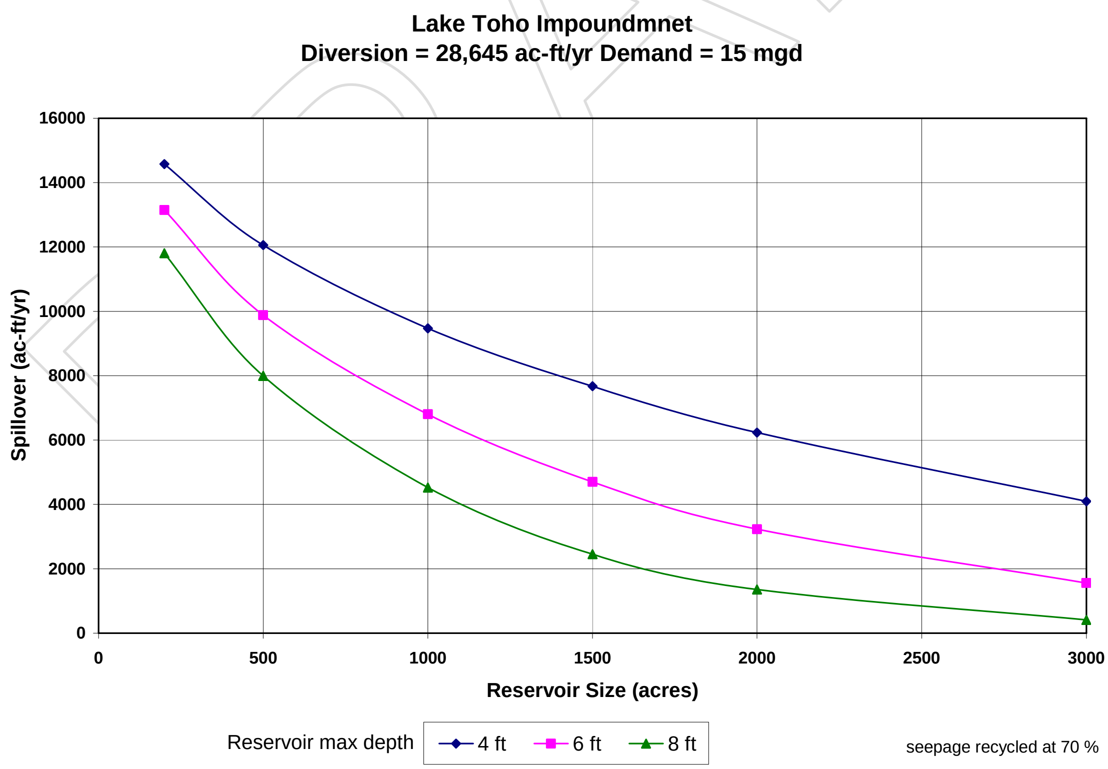

Figure 27. Lake Toho Impoundment Annual Average Spillover for the 15 MGD Demand Level.

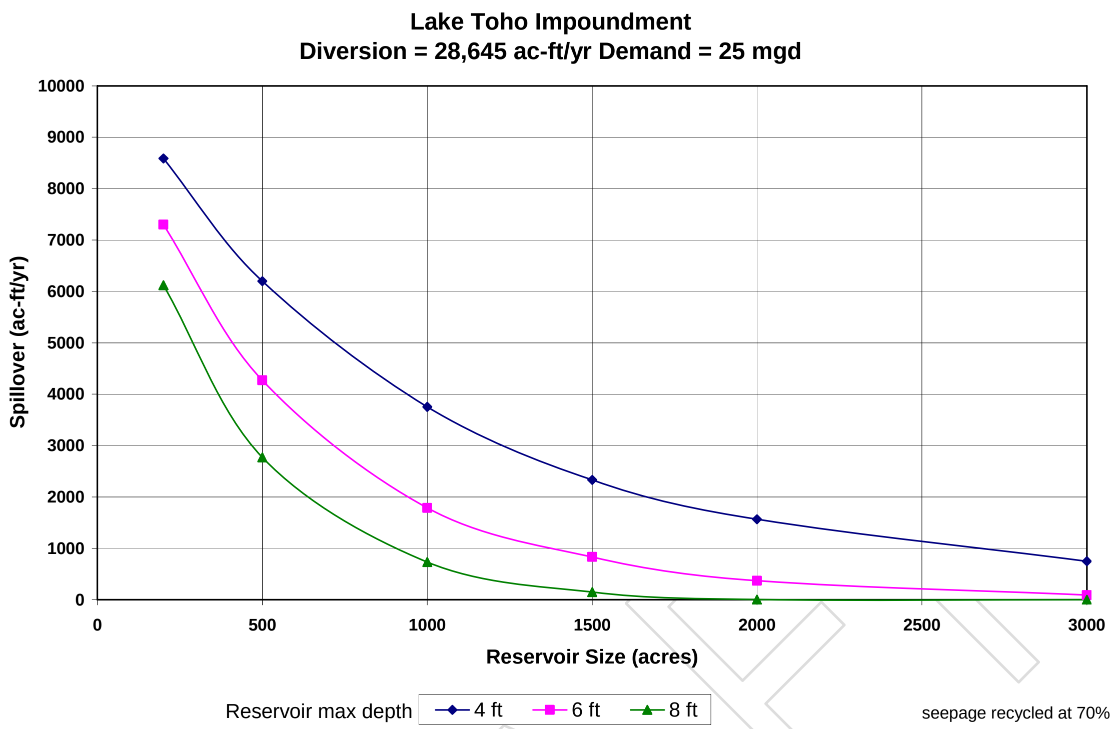

Figure 28. Lake Toho Impoundment Annual Average Spillover for the 25 MGD Demand Level.

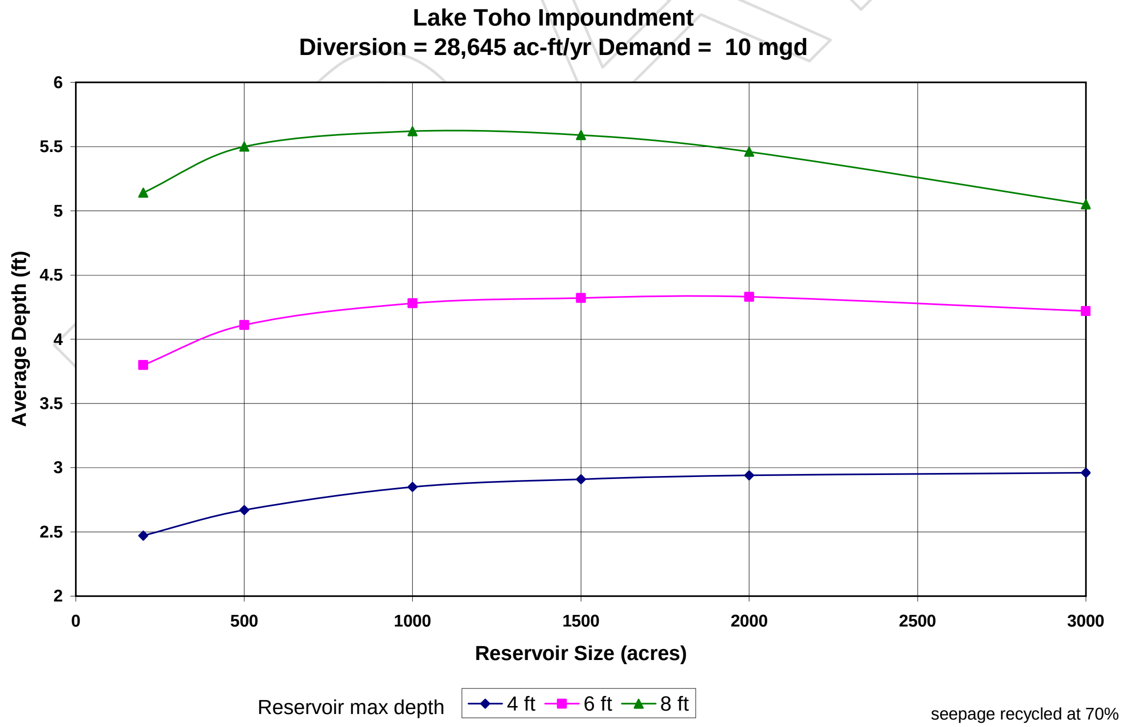

Figure 29. Lake Toho Impoundment Annual Average Water Levels for the 10 MGD Demand Level.

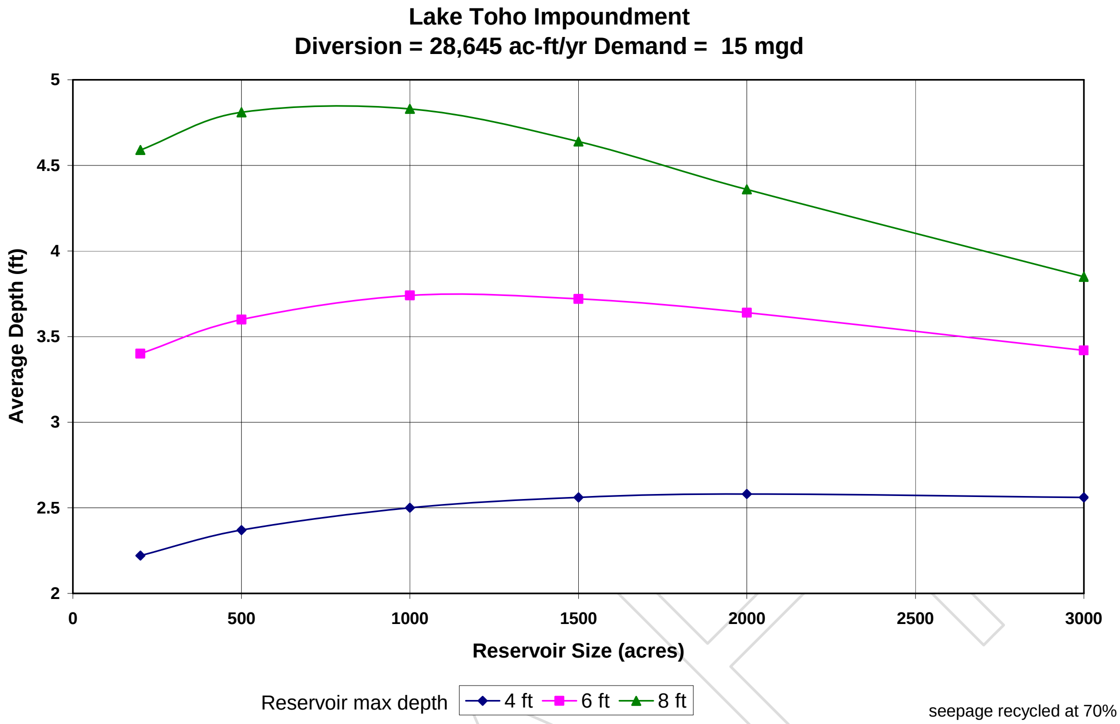

Figure 30. Lake Toho Impoundment Annual Average Water Levels for the 15 MGD Demand Level.

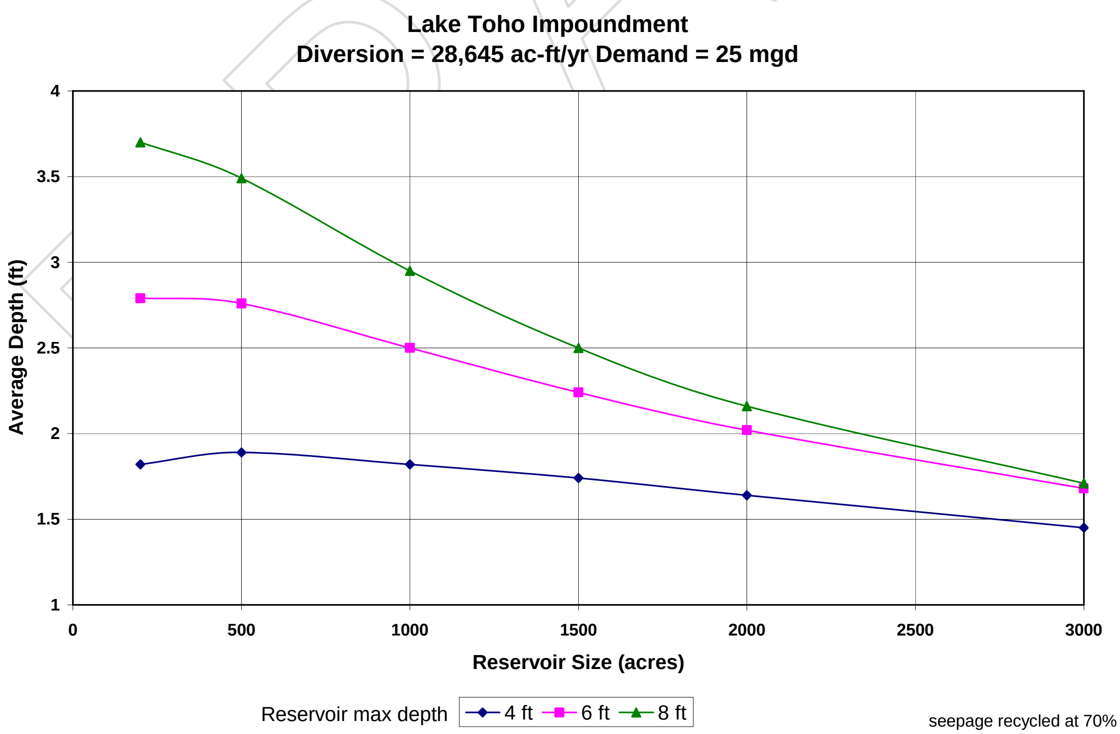

Figure 31. Lake Toho Impoundment Annual Average Water Levels for the 25 MGD Demand Level.

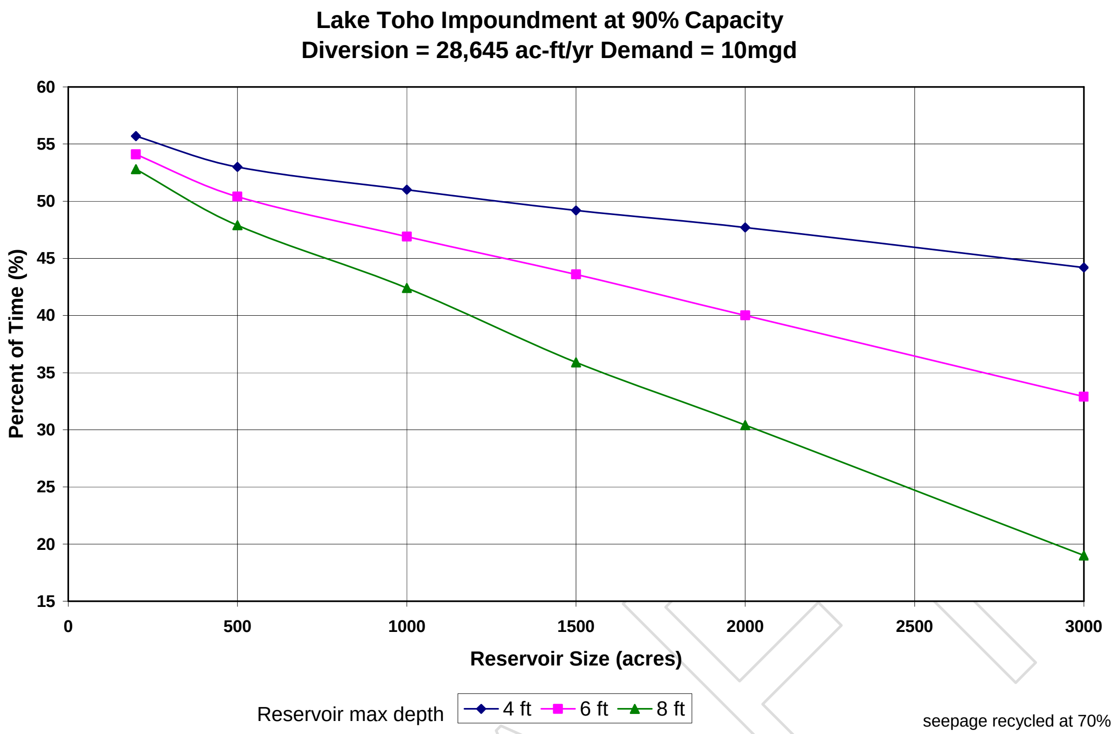

Figure 32. Percent of Time Impoundment at 90 Percent Capacity for the 10 MGD Demand Level.

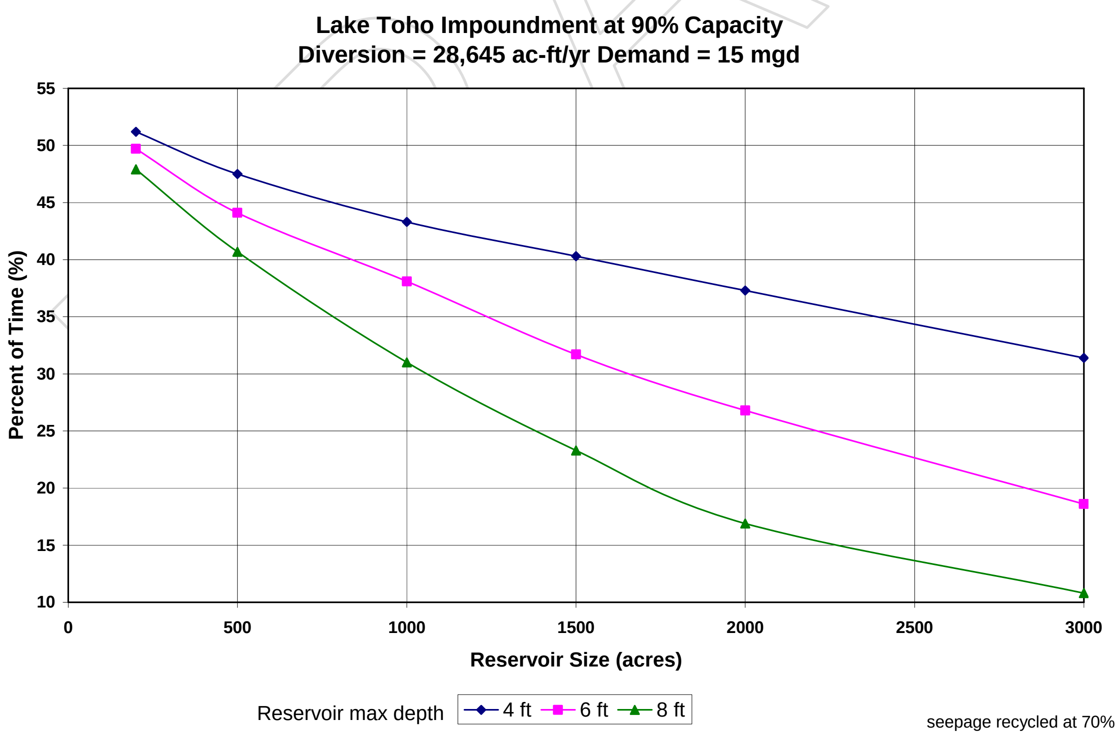

Figure 33. Percent of Time Impoundment at 90 Percent Capacity for the 15 MGD Demand Level.

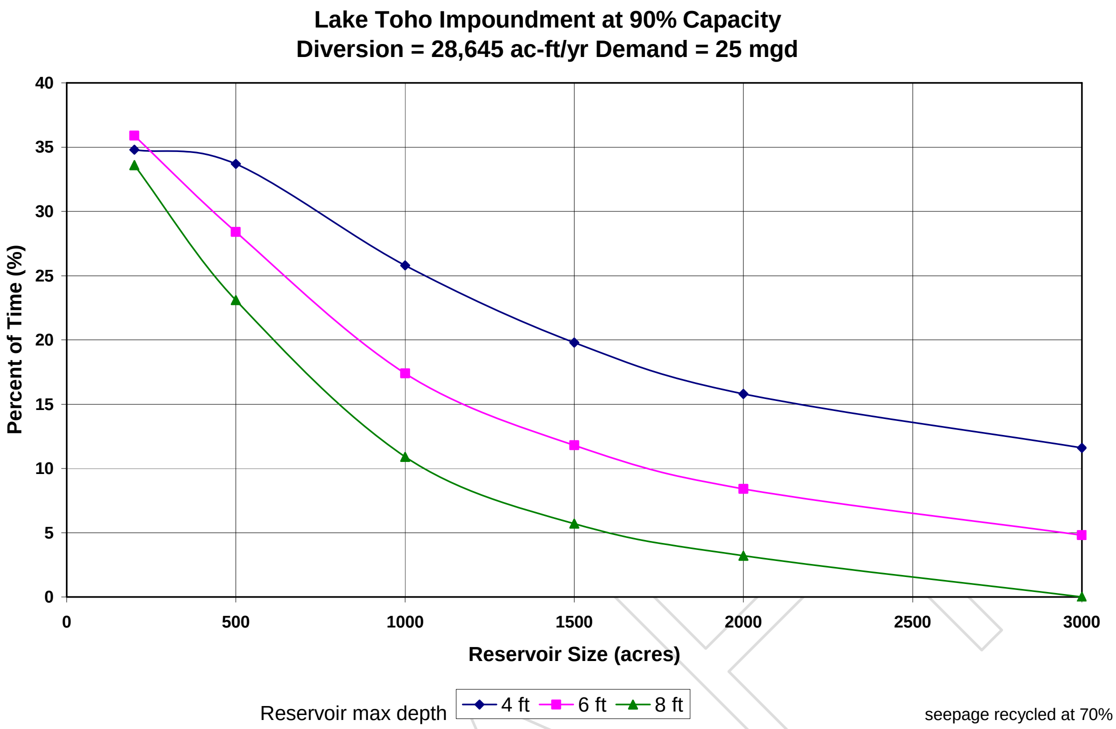

Figure 34. Percent of Time Impoundment at 90 Percent Capacity for the 25 MGD Demand Level.

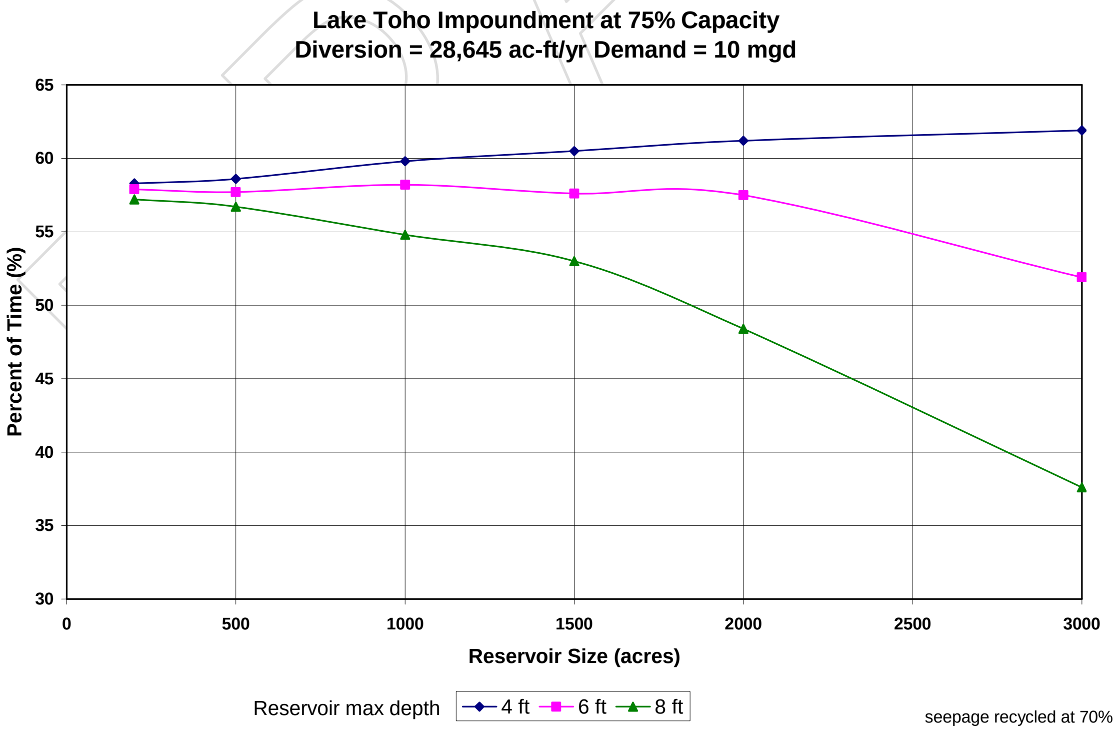

Figure 35. Percent of Time Impoundment at 75 Percent Capacity for the 10 MGD Demand Level.

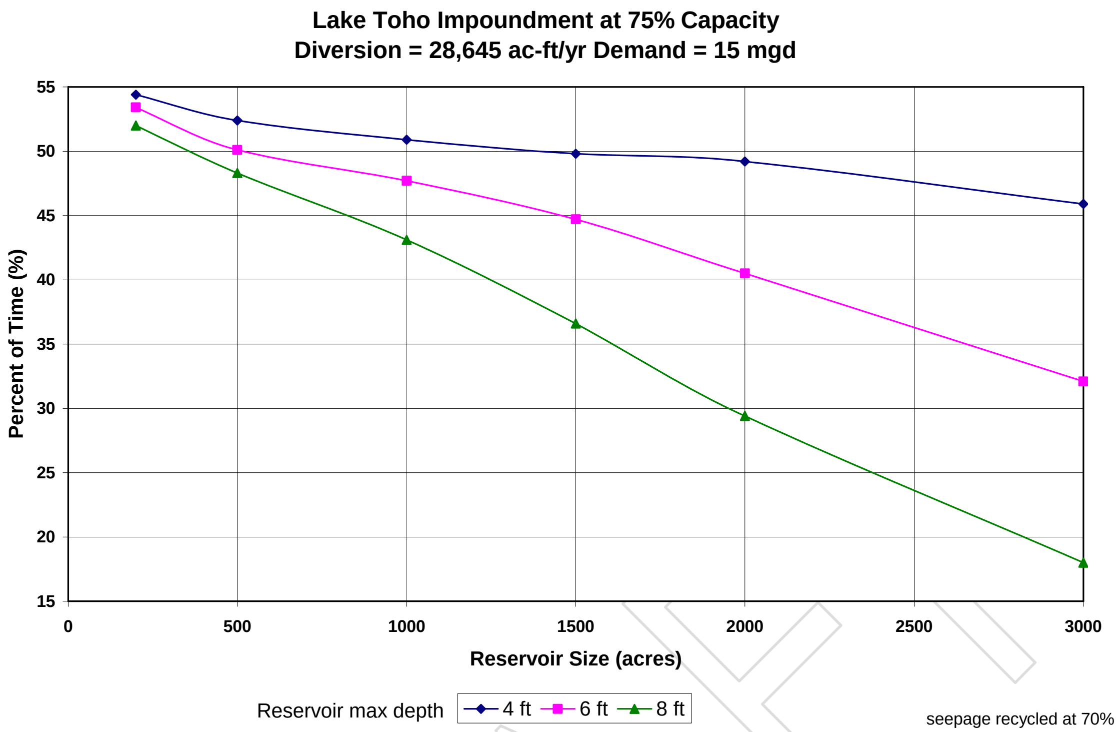

Figure 36. Percent of Time Impoundment at 75 Percent Capacity for the 15 MGD Demand Level.

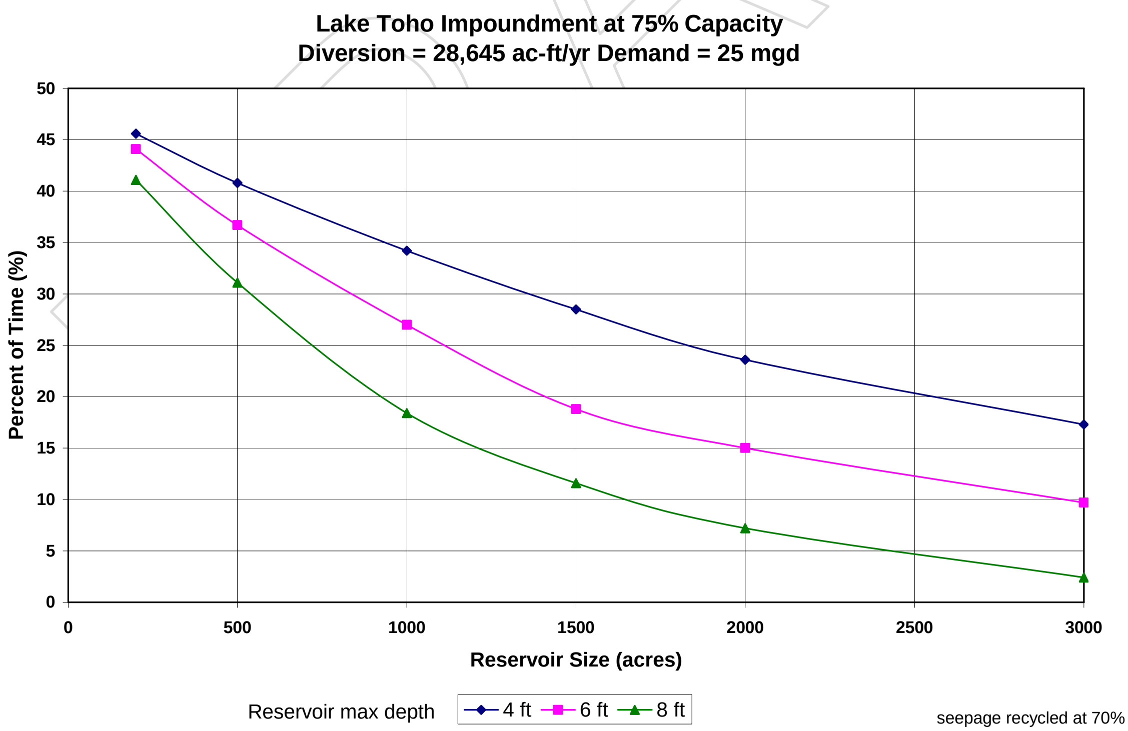

Figure 37. Percent of Time Impoundment at 75 Percent Capacity for the 25 MGD Demand Level.

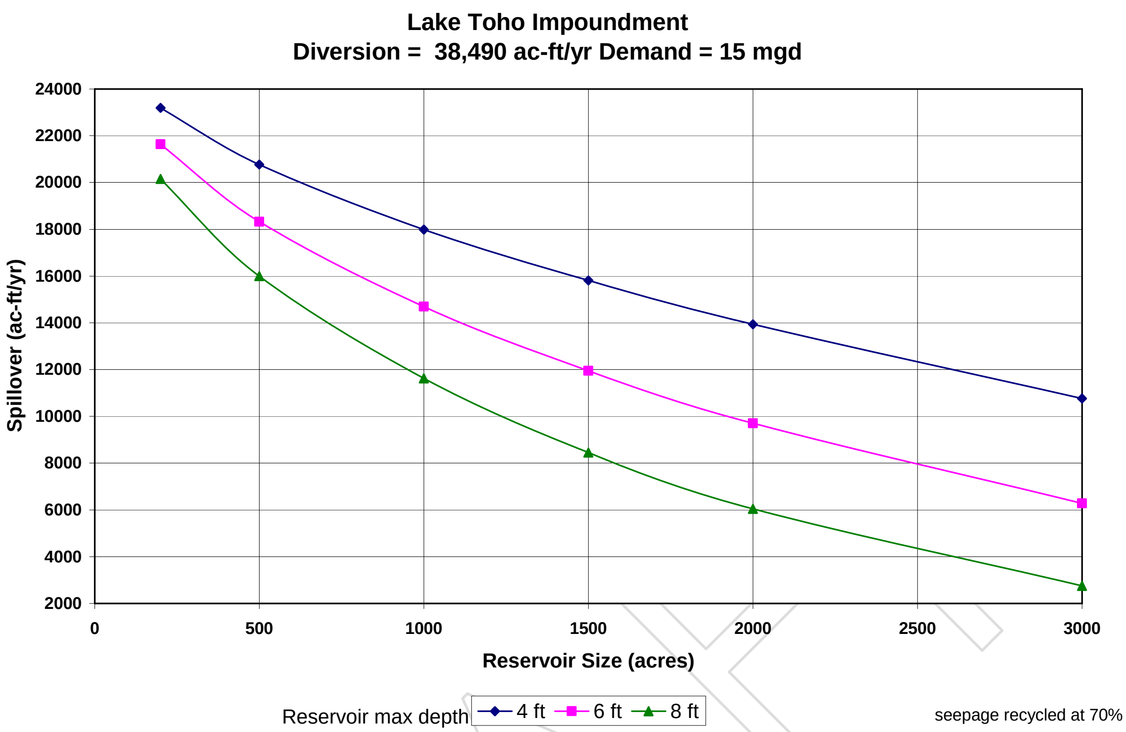

Figure 38. Lake Toho Impoundment Annual Average Spillover for the 15 MGD Demand Level..

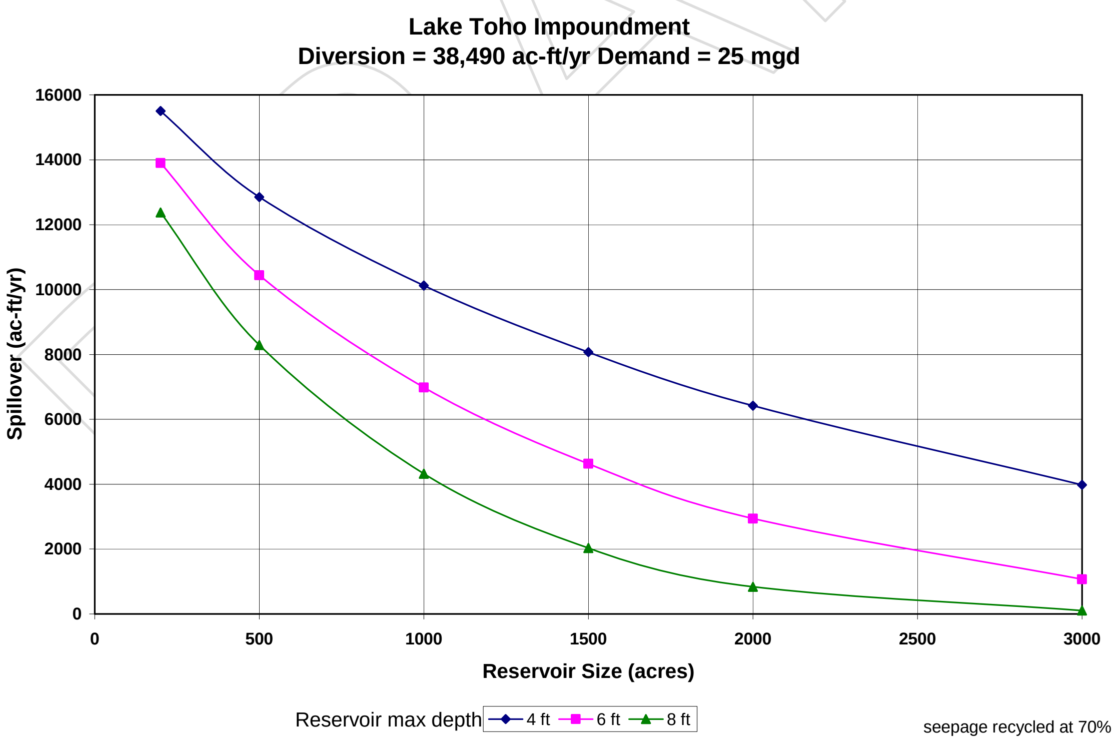

Figure 39. Lake Toho Impoundment Annual Average Spillover for the 25 MGD Demand Level.

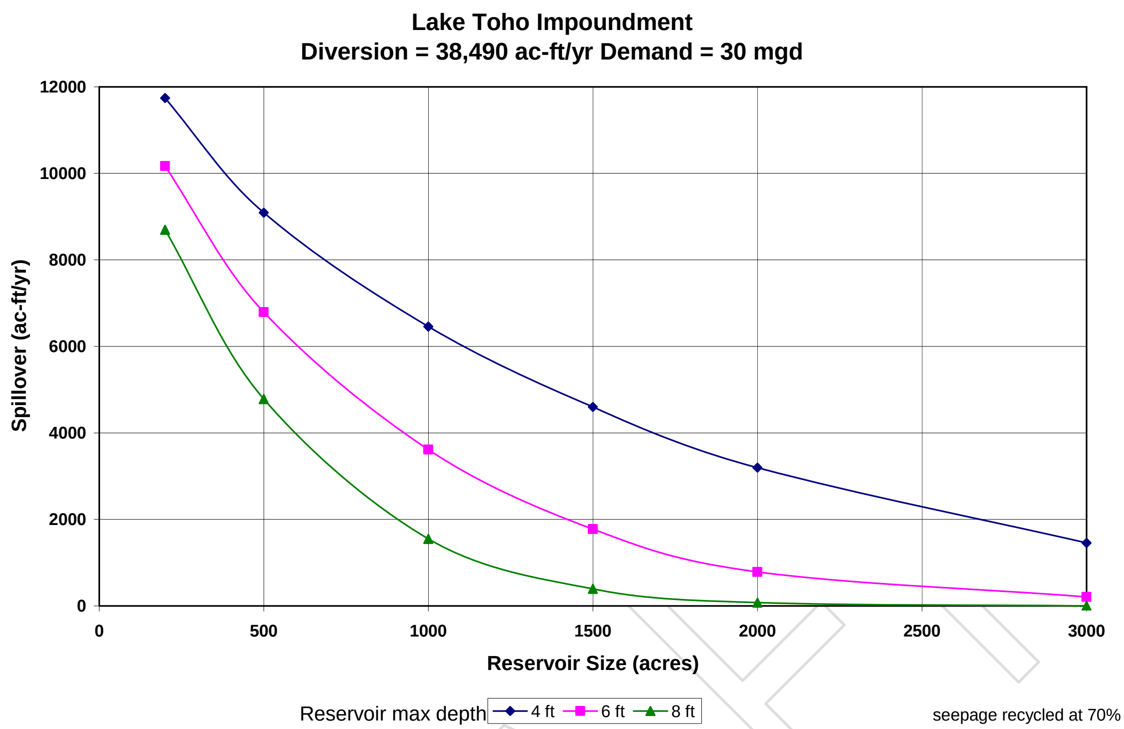

Figure 40. Lake Toho Impoundment Annual Average Spillover for the 30 MGD Demand Level.

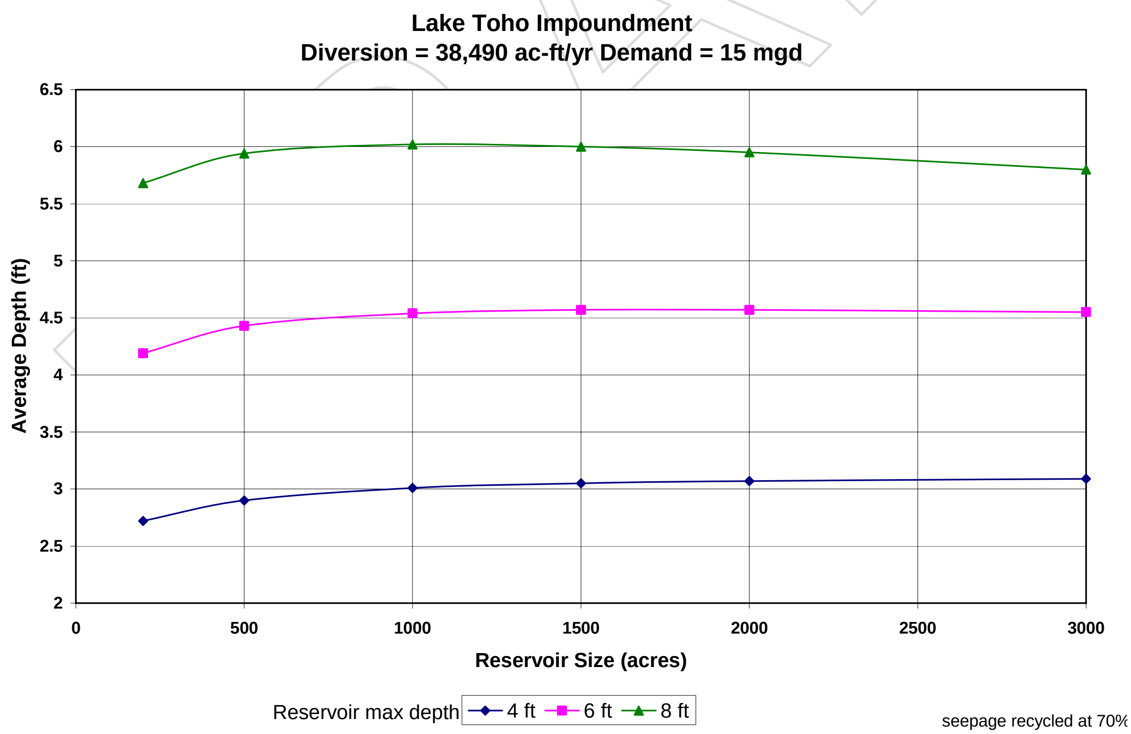

Figure 41. Lake Toho Impoundment Annual Average Water Levels for the 15 MGD Demand Level.

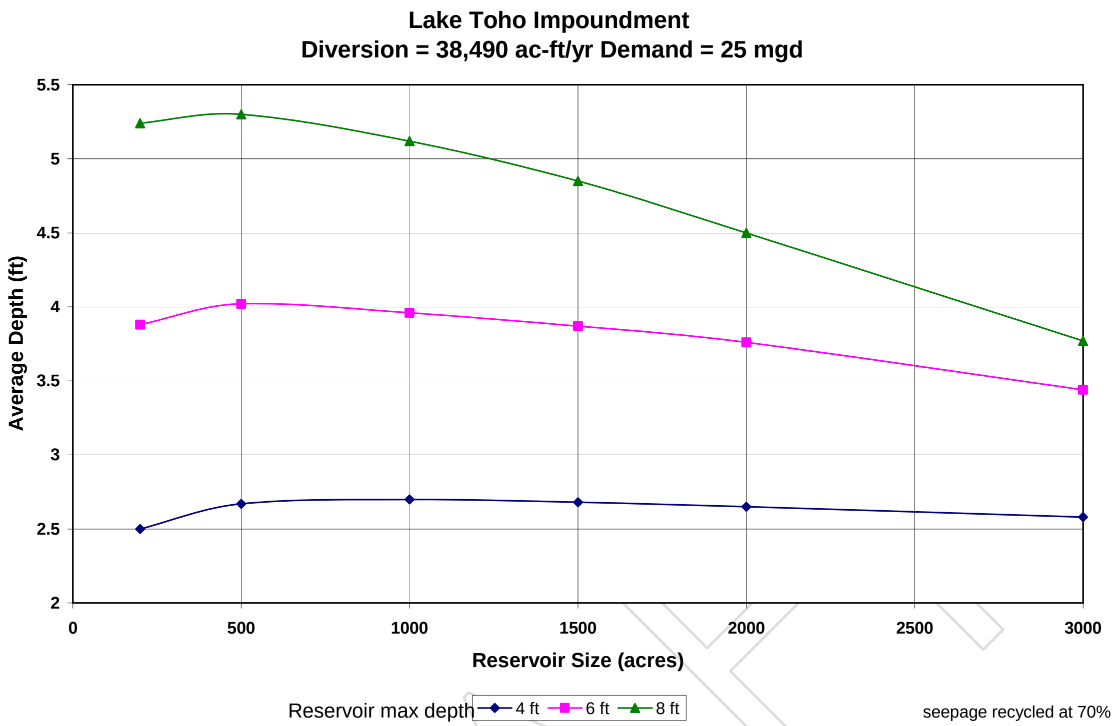

Figure 42. Lake Toho Impoundment Annual Average Water Levels for the 25 MGD Demand Level.

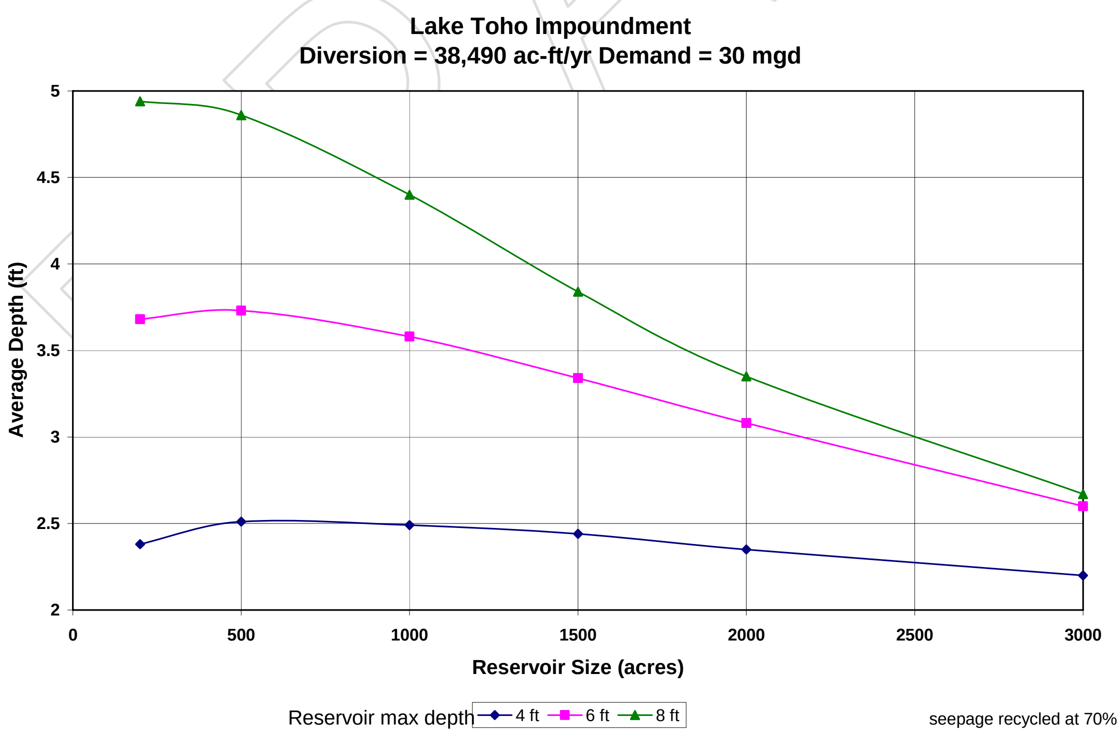

Figure 43. Lake Toho Impoundment Annual Average Water Levels for the 30 MGD Demand Level.

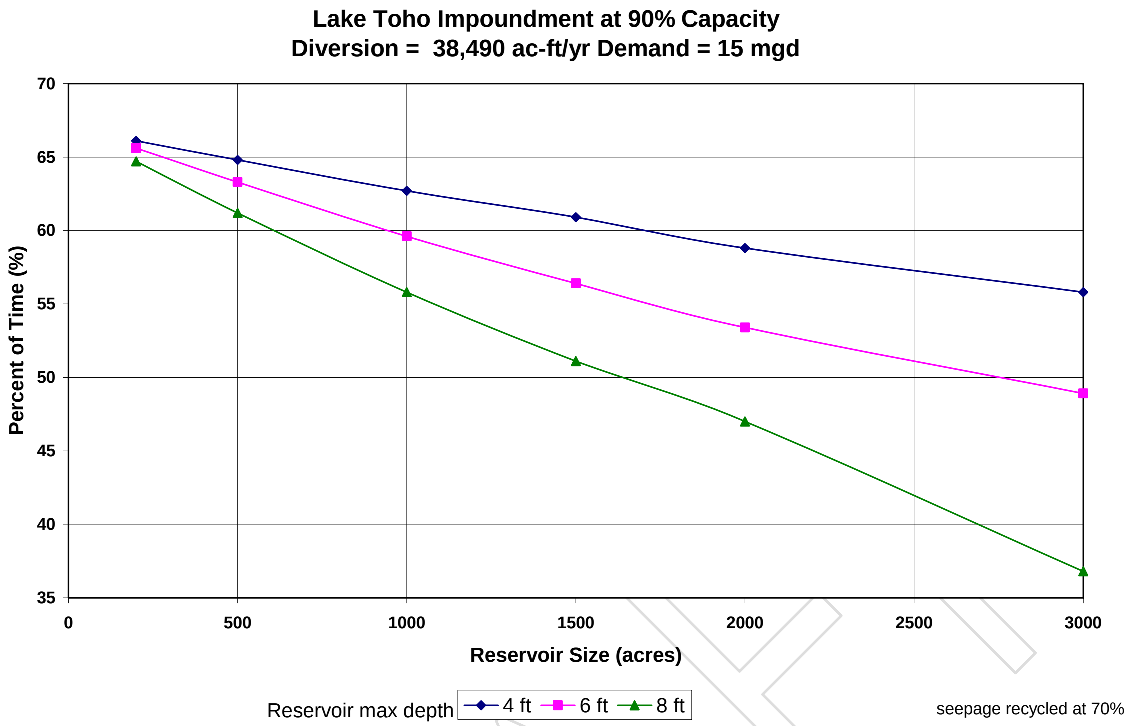

Figure 44. Percent of Time Impoundment at 90 Percent Capacity for the 15 MGD Demand Level.

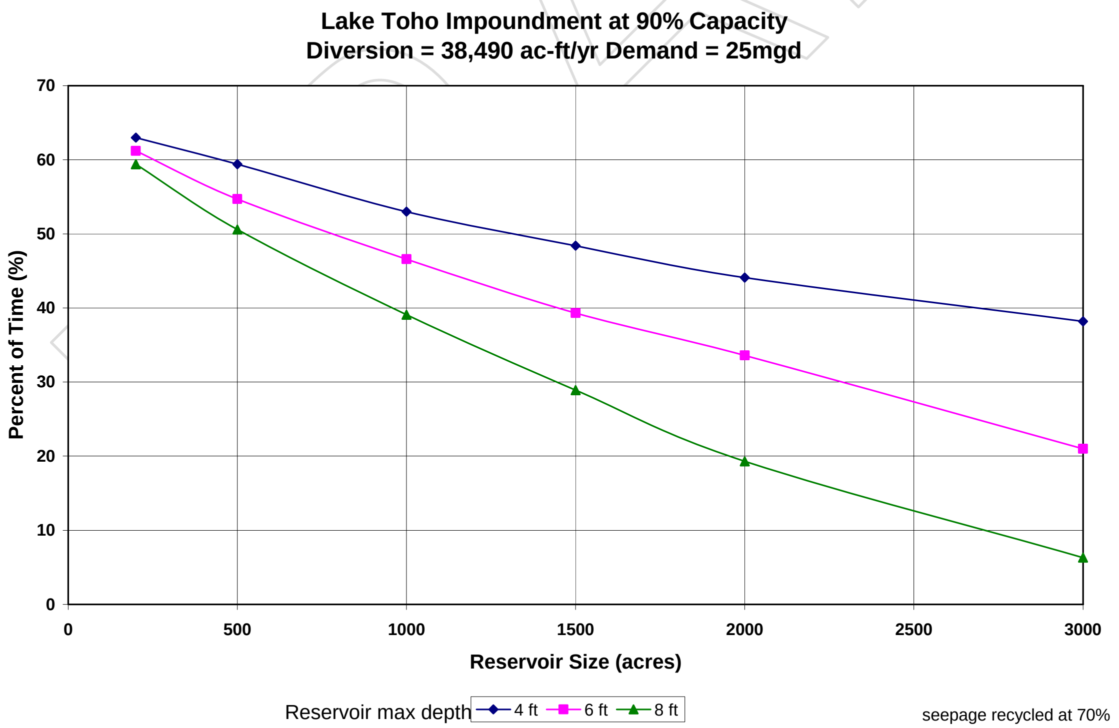

Figure 45. Percent of Time Impoundment at 90 Percent Capacity for the 25 MGD Demand Level.

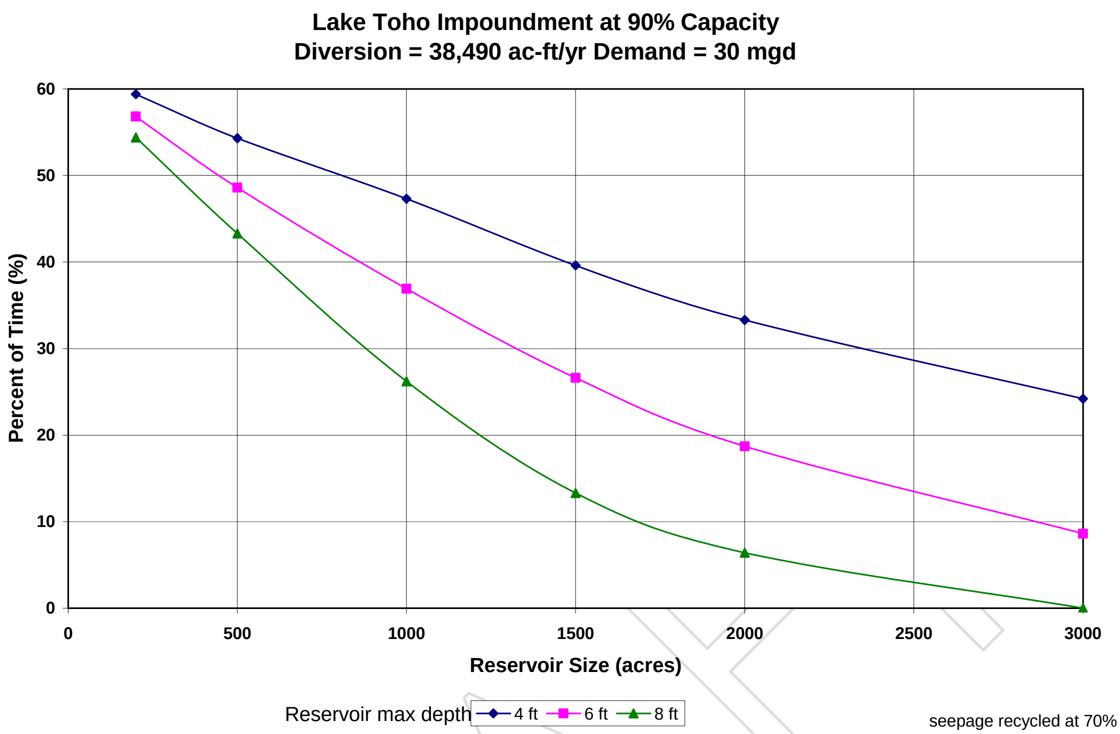

Figure 46. Percent of Time Impoundment at 90 Percent Capacity for the 30 MGD Demand Level.

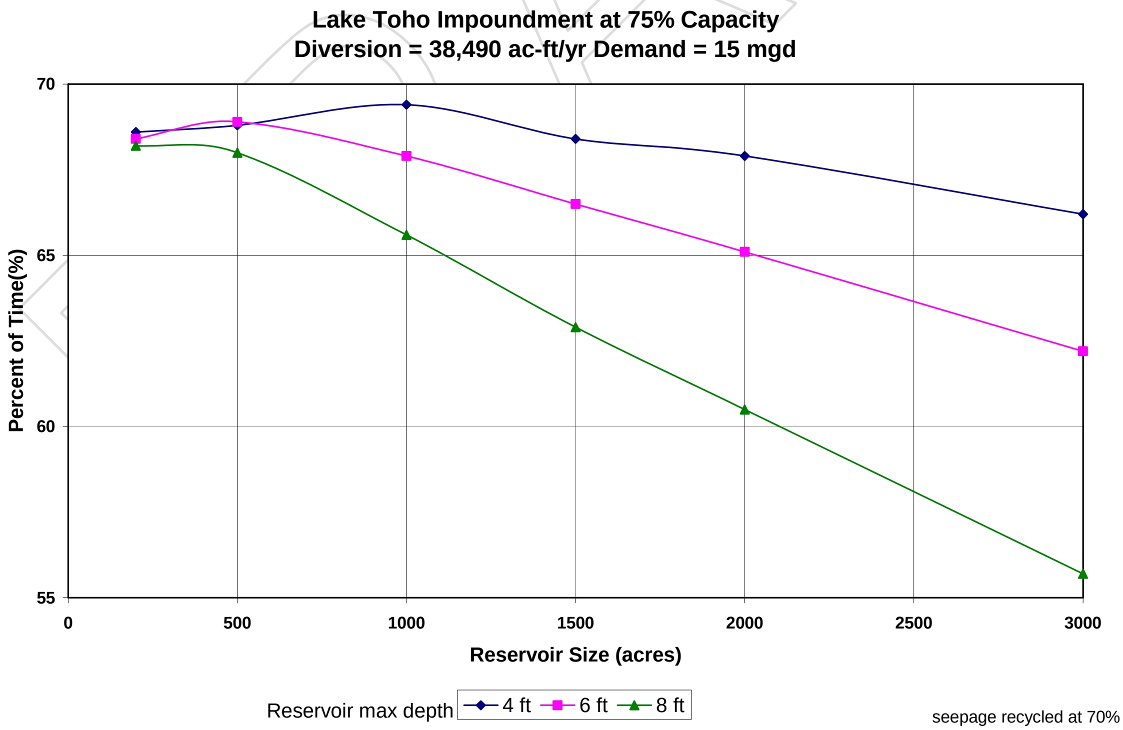

Figure 47. Percent of Time Impoundment at 75 Percent Capacity for the 15 MGD Demand Level.

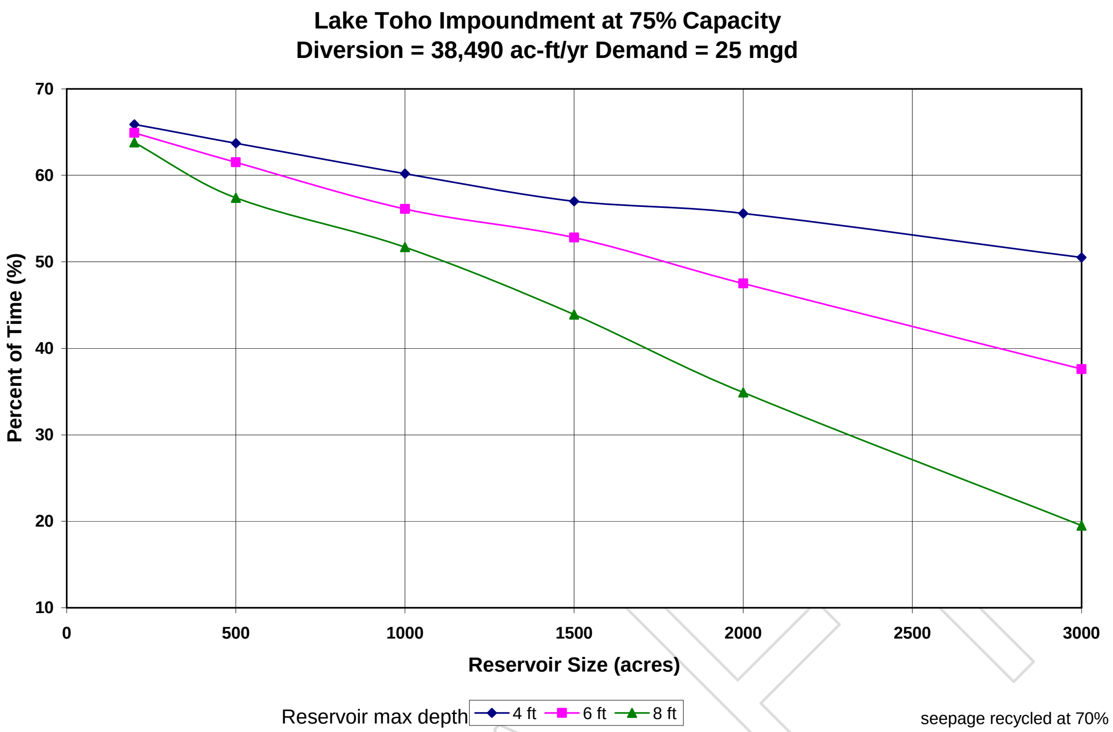

Figure 48. Percent of Time Impoundment at 75 Percent Capacity for the 25 MGD Demand Level.

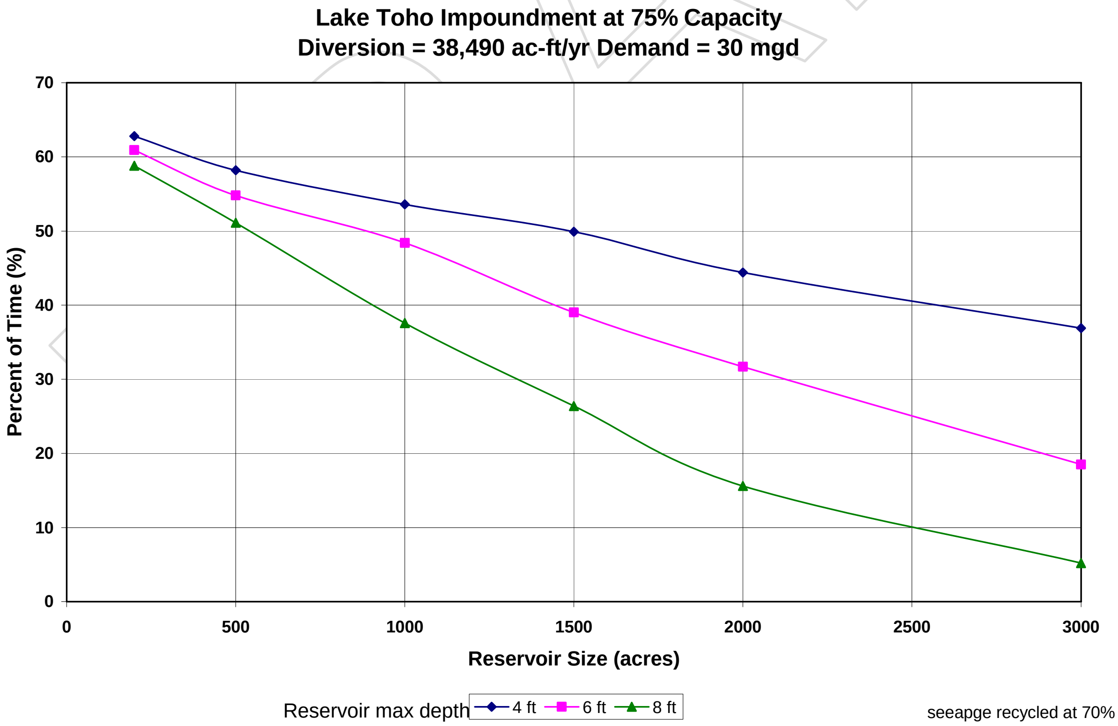

Figure 49. Percent of Time Impoundment at 75 Percent Capacity for the 30 MGD Demand Level.

TECHNICAL MEMORANDUM:

Alternative Water Supply Projects Cost Estimation – Potable Water Supply using Brackish Water as Source from Upper Floridan Aquifer in Eastern Osceola County

This technical memorandum summarizes the conceptual design and provides planning level cost estimates for a potable water supply project using the Upper Floridan Aquifer (UFA) in eastern Osceola County as the source of raw water. To perform this cost estimate, a new saline water wellfield (within the Floridan Aquifer) was identified in eastern Osceola County, 25 miles from a local utility connection point. The water quality is of such saline and total dissolve solids (TDS) concentrations that a membrane treatment process is required for potable water delivery.

The following project components are included in the conceptual design:

- Wellfield site (land) for raw water production.
- Water treatment facilities, including raw water main and groundwater storage tank(s).
- Water delivery system, including a 25-mile pipeline and associated pumping facilities.
- Deep injection well for the disposal of concentrate.

The project conceptual design and associated cost estimates are provided for a range of water supply deliveries involving 10, 20 and 40 million gallons per day (mgd).

Well and Wellfield Design

Based on the preliminary water quality data, suggested well dimensions and yields are provided in **Table 9**.

Table 9. Proposed Well Dimensions and Well Yields.

Casing Diameter (inches)	Casing Depth (feet)	Total Depth (feet)	Well Yield (mgd)
20	600	1,000	2.0

Table 10 shows, for a range of water treatment plant capacities, the required maximum raw water demand based on the recovery rate of 80 percent, and the number of primary and standby wells.

Table 10. Estimated Raw Water Demand and Number of Wells.

Water Treatment Plant Capacity (mgd)	Maximum Raw Water Demand (mgd)	Number of Wells (primary + standby)
10	12.5	7 + 1
20	25.0	13 + 1
40	50.0	25 + 2

Each well would be equipped with a submersible pump and aboveground equipment including flow control elements. For cost estimation purposes, a spacing of 1,000 feet between the wells is assumed.

Water Treatment Plant Technology

Preliminary water quality data (chlorides 375–500 mg/L, TDS 900-1,100 mg/l) indicates that a water treatment technology using a nanofiltration membrane that rejects 85 percent of salt (sodium chloride) and 99 percent of total hardness, or a ultralow pressure (ULP) reverse osmosis (RO) membrane could be adequate to provide the necessary level of treatment. A thin film composite (TFC) ULP RO membrane (model TFC 18061 ULP MegaMagnum, Koch Membrane Systems Inc.) was selected for a planning level cost estimate analysis.

Typical operating pressure for a TFC ULP membrane is within the 75–175 psi range. It provides a minimum chloride ion rejection rate of 97.5 percent. Each membrane element is 61 inches in length and 18 inches in diameter, providing a membrane area of 2,800 square feet. This is seven-times the area of a typical 40-inch by 8-inch membrane element, and allows for up to 40 percent reduction in the membrane trains housing floor space, and significant savings on the civil side of a project. Reduction in the construction time and costs, as well as operation and maintenance costs, should be expected. The planning level costs are based on the preliminary design report for the Lake Region Water Treatment Plant (CDM 2004), adjusted for the use of larger membrane elements and reduction in the process building floor space. The cost for the membrane element was obtained from the Koch Membrane Systems sale manager for the southeast region in Orlando, Florida, and is in the $3,000–$3,200 range. A set of 30 elements is capable of producing 1.0 MGD of permeate.

Water Delivery System Hydraulic Design

A hydraulic analysis for a 25-mile pipeline delivery system is provided to estimate the required pipe diameter and corresponding head losses for three water treatment plant capacities. The number of booster pumps to overcome the head loss within the pipeline system is also provided. The analysis does not include any hydraulic modeling of the water distribution system to the end user. Accordingly, the costs associated with the water distribution system to the end user, including the costs of high pressure service pumps, are not part of this analysis.

A Hazen-Williams equation was used to estimate the pipe flow velocity and head losses. The Hazen-Williams discharge coefficient, C, is assumed to be 150, corresponding to the high density polyethylene (HDPE) pipe material. In addition to being more cost-efficient as compared with a more traditional ductile iron material, HDPE pipe is also non-corrosive and significantly lighter. The HDPE pipe can be assembled in long sections on the ground, which shortens the construction time and time the trench stays open. **Table 11** details the flow, length of pipe, pipe diameter and resulting velocity and head loss for each water treatment plant capacity.

Table 11. Delivery System Hydraulic Analysis.

Plant Capacity (mgd)	Flow (cfs)	HDPE Pipe Diameter (inches)	Length (feet)	Velocity (fps)	Head Loss (feet)
10	15.5	24	132,000	4.98	320
10	15.5	30	132,000	3.17	108
20	30.9	36	132,000	4.39	160
40	61.9	48	132,000	4.93	142

For the 10-MGD plant capacity, the 24-inch diameter HDPE pipe is selected. Although this scenario requires a four-stage delivery system with a booster pump station installed every 6.25 miles (25 miles divided by four) to overcome a 320-foot head loss, the cost of a 24-inch pipe installation is significantly lower than that of a 30-inch pipe system, which would require only a two-stage delivery system. **Table 12** provides unit costs for material and labor from the *CostWorks 2004 Cost Estimation Manual* (CostWorks 2004). It can be estimated from **Table 12** that the 24-inch pipe diameter option is approximately $4.0 million less than the 30-inch diameter option.

Table 12. Unit Costs for Water Delivery System.

Description	Qty	Unit	Bare Mat.	Bare Labor	Bare Equip.	Unit Cost
Excavation and compaction for concrete base, pumps	1.0	Ea.	0.0	860.0	540.0	1,400.0
Pure reinforce concrete base slab for pumps 6'x6'x1.5'	36.0	SF	42.0	26.0	16.0	3,024.0
8 cfs, 3600 GPM, horizontal water pump at 60 ft head	1.0	Ea.	35,000.0	8,500.0	2,100.0	45,600.0
8 cfs, 3600 GPM, horizontal water pump at 80 ft head	1.0	Ea.	38,000.0	8,600.0	2,300.0	48,900.0
16 cfs, 7200 GPM, horizontal water pump at 100 ft head	1.0	Ea.	52,000.0	9,600.0	3,200.0	64,800.0
21 cfs, 9425 GPM, horizontal water pump at 80 ft head	1.0	Ea.	65,000.0	12,000.0	3,800.0	80,800.0
Electrical works	1.0	Ea.	935.0	1,030.0	280.0	2,245.0
High density polyethylene pipe of 24" diameter	1.0	Ea.	58.0	20.0	32.0	110.0
High density polyethylene pipe of 30" diameter	1.0	LF	84.0	24.0	35.0	143.0
High density polyethylene pipe of 36" diameter	1.0	LF	120.0	36.0	50.0	206.0
High density polyethylene pipe of 48" diameter	1.0	LF	145.0	42.0	65.0	252.0

SF = square foot.
LF = linear foot.
Mobilization & demobilization @ 6% of subtotal cost.
Markup @ 20% of subtotal cost.

For each plant capacity, the following total number of pumps (including standby pumps) is selected:

- For a 10-MGD plant, 12 pumps at 3,600 GPM and 80 foot head each (two online/one standby times four stages).
- For a 20-MGD plant, six pumps at 7,200 GPM and 100 foot head each (two online/one standby times two stages).
- For a 40-MGD plant, eight pumps at 9,425 GPM and 80 foot head each (three online/one standby times two stages).

Concentrate Disposal

The concentrate (brine) would be disposed of using a deep well injection to be located at the water treatment plant site. A second monitoring well will also be required. In the case of potential well problems, sufficient on-site space and construction of a temporary lined storage pond for the concentrate should be planned.

Although the cost for the deep well injection concentrate disposal is included in calculations of planning level costs, the presence of a nearby wastewater/reclaimed water treatment facility could provide for the concentrate disposal without the need for a deep well injection system.

Planning Level Cost Estimates

Table 13 summarizes planning level costs for the alternative, including the wellfield costs. The wellfield costs include cost for the wastewater treatment plant (WTP) facilities, which is comprised of cost for the raw water main, pretreatment of raw water, post treatment of permeate, a membrane treatment system, a ground storage tank, chemical systems and storage. The wellfield costs also include cost for the site work, which consists of cost for the finished water delivery system, and cost for the concentrate disposal system. All component cost data include installation, construction and project implementation costs, including engineering design, permitting and administration costs. In addition, the cost data derived from the CostsWorks manual includes a 20-percent markup to account for HDPE pipe cost fluctuations due to increasing petroleum prices. Land costs include the cost of easement for the pipeline corridor and land for the water treatment plant.

Equivalent Annual Cost is a total annual life cycle cost of a project based on the economic service life of different project components and time value of money criteria. The Equivalent Annual Cost accounts for total capital cost and operations and maintenance costs, with the facility operating at average day design capacity. Economic service life varies from five years for reverse osmosis membranes to 40 years for water conveyance structures, such as pipelines and collection and distribution systems. An interest rate of 5.625 percent is used in all economic calculations.

Table 13. Planning Level Cost Estimates for Wellfield, WTP and Pipeline System from Western Osceola County.

System Component	10 MGD WTP Capacity	20 MGD WTP Capacity	40 MGD WTP Capacity
Production Wells	$4,800,000	$8,400,000	$16,200,000
WTP Facilities, including:	$12,950,000	$22,350,000	$36,850,000
a. Process building	$1,192,400	$2,057,900	$3,393,000
b. Pre- and Post-treatment systems	$3,800,150	$6,558,500	$10,813,400
c. Membrane treatment system	$2,547,250	$4,396,200	$7,248,400
d. Ground storage tank	$1,480,400	$2,554,600	$4,212,000
e. Chemical systems and storage	$581,400	$1,003,500	$1,654,500
f. Site work	$3,348,600	$5,779,300	$9,525,700
Raw Water Main (10% of WTP facilities)	$1,295,000	$2,235,000	$3,685,000
Water Delivery System	$19,100,000	$34,785,000	$42,772,000
Concentrate Disposal	$4,200,000	$4,400,000	$4,600,000
Subtotal cost, including 25% project implementation cost	$42,345,000	$72,170,000	$104,107,000
Land Cost, including Land Acquisition Cost of 18%	$7,059,200	$8,277,400	$9,545,600
Contingency @ 20%	$6,351,800	$10,825,500	$15,616,100
Total Project Cost	$55,756,000	$91,272,900	$129,268,700
Annual O&M @ 3% of Construction Cost	$1,270,350	$2,165,100	$3,123,200
Equivalent Annual Cost	$5,732,177	$9,526,290	$13,841,115
Unit Production Cost, $1000/gal	$1.57	$1.30	$0.95

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